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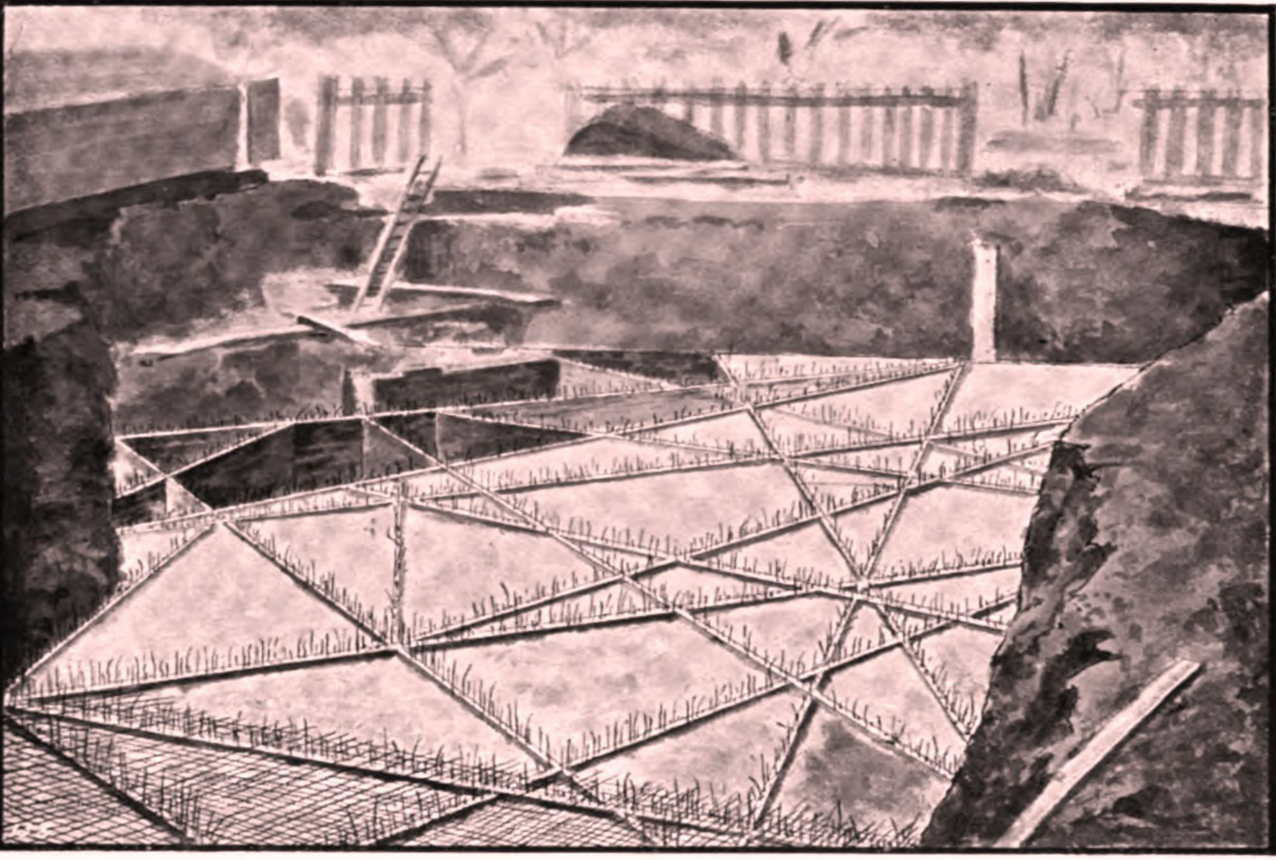

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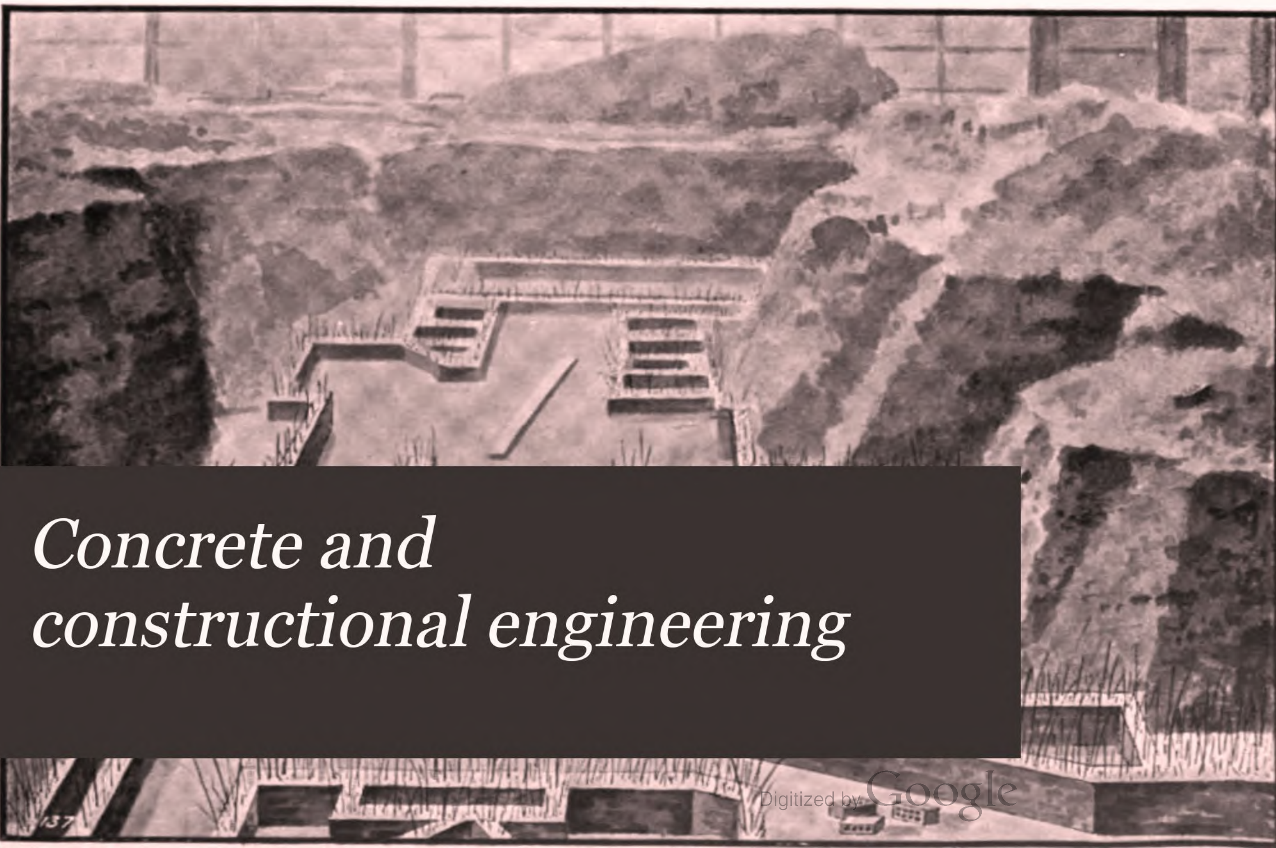

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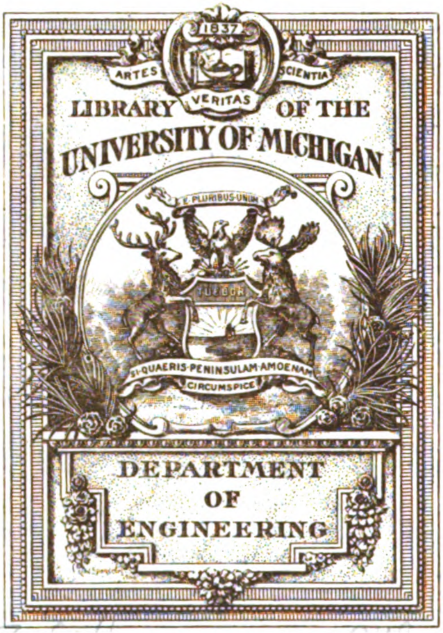
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CONCRETE
AND
CONSTRUCTIONAL ENGINEERING

VOL. I. 1906-7. Nos. 1 to 6.

A Bi-Monthly Journal for Engineers, Architects and Surveyors—Contractors and Builders—and all Workers in Cement, Concrete, Reinforced Concrete, and Constructional Steel.

INDEX
TO
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CONSTRUCTIONAL ENGINEERING

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INDEX.

Articles and Papers at Home and Abroad 70, 152, 235, 319, 401, 483
Architects, International Congress of, Reinforced Concrete at the Aquarium at Milan (New Works in Concrete) 286, 383
Block, Hollow Concrete, Building Construction in the United States, by S. B. Newberry, Cleveland, U.S.A. 118
Blocks, Types of Hollow Concrete, in the States, and Their Patents, by W. M. Torrance. Illustrated 206
Bournemouth, Concrete Water Tower at (New Works) 133
Bridges, Reinforced Concrete. A series of Articles, by W. Noble Twelvetrees, M.I.Mech.E. Illustrated. ... 171, 261, 341, 417
British Patent Rights in Reinforced Concrete Piles: Mouchel and Another *versus* Coignet and Others, by a Barrister-at-Law 280
Building Act, Steel Skeleton Construction and the London. By W. Noble Twelvetrees, M.I.Mech.E. Illustrated 17
Bush Terminal Warehouse, U.S.A. (New Works in Concrete) 467
Cement Warehouse, Grosvenor Road (New Works in Concrete) 467
Champagne-sur-Mer, France, Reinforced Concrete Water Tower (New Works in Concrete) 217
Chimneys, Reinforced Concrete (New Uses) 137
Concrete Age, The Advent of the. By Lieut.-Col. J. Winn, R.E., M.Inst.C.E. Illustrated 7
Concrete Building Construction, Safeguards Against Freezing in. Illustrated. 51
Congress of Architects, Reinforced Concrete at the International. Correspondence ... 286
Corrosion: The Preservation of Iron and Steel. By B. H. Thwaite, C.E. Illustrated 46, 105
Cracks, Hair and other Minor Cracks in Concrete Surfaces. By Albert Moyer 126

CORRESPONDENCE.

Diagram for T-Beams of Reinforced Concrete, A 150
Earthquake Districts, Reinforced Concrete for 399
Fictitious Portland Cement 150
Corrosion: The Preservation of Iron and Steel. By B. H. Thwaite, C.E. Illustrated 46, 105
Cracks, Hair and other Minor Cracks in Concrete Surfaces. By Albert Moyer ... 126

EDITORIAL NOTES.

Announcement Regarding "Concrete and Constructional Engineering" 1
Architects, The Royal Institute of British, and Reinforced Concrete 3, 75
Book on Reinforced Concrete, A Notable (Mr. Charles F. Marsh's) 405
Commission, A Special, on Concrete Aggregates 408
Committee, The Reinforced Concrete 155, 408
Concrete in Everyday Use 322
Congress at Milan, The International Fire Service ("Reinforced Concrete as a Fire Resistant") 157
Congress of Architects, The 239
Contemporaries, Our Special 3
Defects in Reinforced Concrete that are Remediable 404
Deterioration of Reinforced Concrete Roofs in Egypt, The 78
Failures in Reinforced Concrete ... 239, 403
Fictitious Portland Cement ... 5, 76, 322, 407
Fire Resistant, Concrete as a 4, 157, 240, 323
Fire Service and Reinforced Concrete, The 4
Fire Tests with Concrete 5
Fire Test, A Recent 323
French Rules as to Reinforced Concrete, The New 321
Government, H.M., and Reinforced Concrete 403
Inquiries on Matters of Technical Importance, Independent 404
Inquiry, An Important Government, on Concrete in the U.S.A. 76
International Standards for Reinforced Concrete 239
Litigation as to Reinforced Concrete ... 241
Malta Case on the Fictitious Label, The... 407
Marsh's, Mr. Charles F., "Reinforced Concrete" 405
Ocean Wharves for the Thames, Proposed Antiquated 406
Restrictions against Bad Concrete, Reasonable 77
San Francisco, Constructional Work at ... 240
San Francisco Fire, The... 157
Sea Water, Concrete Exposed to 242
Standards Committee on Cement, The 158, 241
Standards for Reinforced Concrete, International 155
Testing Association, The International ... 321
Venice under Repair 324
Vincent's, Sir Howard, Bill as to the Origin of Materials 77

France, the Historical Evolution of Reinforced Concrete in. By N. de Tedesco. Illustrated 159

Freezing, Safeguards Against, in Concrete Building Construction. Illustrated ... 51
French Rules as to Reinforced Concrete, The New 330, 461
Farm, Concrete on the (New Uses for Concrete) 312
Fence Posts, Reinforced Concrete (New Uses for Concrete) 392
Fictitious "Portland" Cement. By a British Cement Maker 368
Fire Resistant, Reinforced Concrete as a. By Captain Sewell, U.S.A. Army. Illustrated 243
Fortification Works in the United States, Waterproofing Concrete on. By Emile Low, M.Am.Soc.C.E. 357
Foundations of Buildings, Reinforced Concrete for. By Charles F. Marsh, M.Inst.C.E. Illustrated 35
Gasholder Tank, A Reinforced Concrete (New Uses for Concrete) 475
Germany, The Historical Evolution of Reinforced Concrete in. By O. Kohlmorgen. Illustrated 325
Germany, New Works in (New Works in Concrete) 469
Grain Silo at Lissa (Prussia), The Working Drawings of a Reinforced Concrete. Illustrated 361
Great Western Railway, Reinforced Concrete on. By W. Armstrong, M.Inst.C.E. Illustrated 109
Hair Cracks and other Minor Cracks in Concrete Surfaces. By Albert Moyer 126
Indiana, Reinforced Concrete Arch Bridge in (New Works) 131
United States, Reinforced Concrete in the. By Captain Sewell, U.S.A. Army. Illustrated 79
Water Mains, Reinforced Concrete. By H. H. Wyrill, M.Inst.C.E. Illustrated 185
Waterproofing a Concrete Passenger Subway (New Works in Concrete) 218
Waterproofing Concrete on Fortification Works in the United States. By Emile Low, M.Am.Soc.C.E. 357

INDUSTRIAL ASSOCIATIONS.
- German Portland Cement Manufacturers, The Association of 8, 64

INDUSTRIAL NOTES.
- Chimneys, Reinforced Concrete... ... 229, 315
- "Kleine" Patent Fire-Resisting Floor, Tests on a 481
- Proportioning of Structures in Armoured Concrete, The Rational 231
- Reinforced Concrete System with Rigid Shear Members, A 67
- "Vulcanite" Roofing for Concrete Flats... 317
- Italy, The Historical Evolution of Reinforced Concrete in. By O. N. di Montenegro. Illustrated 409

LAWS, RULES AND REGULATIONS.
- Instructions to Inspectors as to Reinforced Concrete Arch Construction on New Railway Works 396
- New York Regulations on "Concrete Steel Construction" 62
- Proposed Rules for Reinforced Concrete in Buildings 148

Lighthouse, "Mile Rock," San Francisco (New Works) 220
Manheim, Reinforced Concrete Bins at (New Works) 134
Memoranda 129, 213, 295, 373, 465
Milan Exhibition: Some Reflections on Reinforced Concrete and Cement Uses after a Visit to the International Exhibition at Milan. By Frederick R. Farrow, F.R.I.B.A. Illustrated 253
Mont de Piété, Milan (New Works in Concrete) 471
Motor Garage at New York (New Works in Concrete) 309
Mouchel and Another *versus* Coignet and Others: British Patent Rights and Reinforced Concrete Piles. By a Barrister-at-Law 280
Munich, Reinforced Concrete at: The "Tietz" Stores. Illustrated 27

NEW WORKS IN STEEL.
- Machesney Building of Pittsburg 135
- Newton-le-Willows, Water Tower at (New Works in Concrete) 221
- North-Eastern Railway Goods Station, Newcastle (New Works in Concrete) ... 303
- Piles, British Patent Right in Reinforced Concrete. Mouchel and Another *versus* Coignet and Others. By a Barrister-at-Law 280
- Piles, Reinforced Concrete, in Tidal Waters. By A. T. Walmisley, M.Inst.C.E. Illustrated 88
- Pittsburg, The Machesney Building at Pittsburg (New Works in Steel) 135
- Portland Cement, Fictitious. By a British Cement Maker 368
- Preservation of Iron and Steel, The. By B. H. Thwaite, C.E. Illustrated 46, 105
- Railway Sleepers, Reinforced Concrete. By C. H. Kimball. Illustrated.. 269
- Railway Sleepers, Reinforced Concrete. (New Uses for Concrete) 57
- Rainham, Foundations at (New Works in Concrete) 384
- Reinforced Concrete, The Theory of. By Captain Sewell, U.S. Army. Illustrated 193
- Reinforced Concrete as a Fire Resistant (Constructional Lessons from San Francisco). By Captain Sewell, U.S. Army. Illustrated 243
- Reinforced Concrete at Munich: The "Tietz" Stores. Illustrated 27
- Reinforced Concrete Bridges. A Series of Articles. By W. Noble Twelvetrees, M.I.Mech.E. Illustrated 171, 261, 341, 417

NEW WORKS IN CONCRETE.
- Aquarium Building at Milan International Exhibition, The Reinforced Concrete ... 383
- Bins at Manheim 133
- Factories for Messrs. Rowntree & Co., Ltd., York 303
- Footbridge over a Gorge, Concrete Ribbed Arch (Deer Park, U.S.A.) 215
- Foundations at Rainham, Reinforced Concrete 384
- Germany, New Works in 469
- Jefferson Street Reinforced Concrete Arch Bridge, South Bend, Indiana, U.S.A. .. 131
- Lighthouse Construction, Portland Cement Concrete for "Mile Rock" Lighthouse, San Francisco 220
- Reservoir at Bournemouth, New Reinforced Concrete Water 133
- Reservoir in France, Reinforced Concrete 308
- Residence in the United States, Concrete Block 387
- Sea Defence Work, West Hartlepool ... 388
- Strong Room at the Mont de Pieté, Milan, The 471
- Subway Under Railway Tracks, Difficult Waterproofing of a Concrete Passenger 218
- Tunnel, East Boston 466
- Warehouse, Bush Terminal, U.S.A. ... 466
- Warehouse, Cement, Reinforced Concrete ... 467
- Warehouse in High Street, Manchester ... 390
- Water Tower Champagne-sur-Mer, France. Reinforced Concrete 217
- Water-Tower at Newton-le-Willows, New... 221

New Uses for Concrete.
Chimneys, Reinforced Concrete 137
Farm, Concrete on the 312
Fence Posts, Reinforced Concrete 392
Gasholder Tank, A Reinforced Concrete... 475
Railway Sleepers, Reinforced Concrete ... 57
Stringers for Tracks in Mine Shafts, Concrete 223
Transmission Towers, Reinforced Concrete 224

Research Work.
United States Government Advisory Board of Structural Materials, The 139
Reservoir at Chatillon, France (New Works in Concrete) 305
Residence, Concrete Block, in the United States (New Works in Concrete) 388
Ritz Hotel, Steel and Concrete at the. Illustrated 439
Rowntrees' New Factory, York (New Works in Concrete) 303
Rules as to Reinforced Concrete, The New French ... ... 330 and 461

Reinforced Concrete Failures and Their Lessons. Illustrated.
The Collapse of a Building at Bâle ... 275
The Collapse of a Theatrical Scenery Store at Berne 455

Reinforced Concrete for Foundations of Buildings. By Charles F. Marsh, M.Inst.C.E., Illustrated 35
Reinforced Concrete in France, The Historical Evolution of. By N. de Tedesco. Illustrated 159
Reinforced Concrete in Germany, The Historical Evolution of. By O. Kohlmorgen. Illustrated 325
Reinforced Concrete in the United States. By Captain Sewell. Illustrated 79
Reinforced Concrete on the Great Western Railway. By W Armstrong, M.Inst.C.E. Illustrated 109
Reinforced Concrete Piles in Tidal Waters. By A. T. Walmisley, M.Inst.C.E. Illustrated 88
Reinforced Concrete Railway Sleepers. By C. H. Kimball. Illustrated 269
Reinforced Concrete Water Mains. By H. H. Wyrill, M.Inst.C.E. Illustrated 185

Tests With Concrete.
Adhesion of Steel Embedded in Concrete, Some Experiments on the 61
Aggregates, Various Concrete, Under Fire and Water Test... 59
American Tests with Reinforced Concrete, Some 296
Beams, French Official Tests with Reinforced Concrete 144
Bending Test with Reinforced Concrete, Tensile and. By Professor F. Schüle ... 376
Columns, Concrete: Some Remarkable Tests Indicating "Flow" of Concrete under Pressure 141
Floors, Fire Tests with Reinforced Concrete 141, 226, 302
"Flow" of Concrete under Pressure, Some Remarkable Tests Indicating ... 141
French Official Tests with Reinforced Concrete Beams 144
"Kleine" Patent Fire-Resisting Floor, Tests on a 481
Loading Tests in a Reinforced Concrete Factory Building at York 382
Steel Embedded in Concrete, Some Experiments on the Adhesion of 61
Tensile and Bending Tests of Reinforced Concrete. By Professor F. Schüle 376

INDEX TO ADVERTISERS.

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CONCRETE
AND
CONSTRUCTIONAL ENGINEERING

Volume I. No. 1. MARCH, 1906.

ANNOUNCEMENT.

THIS journal has been founded with the object of meeting the growing demand for reliable technical and economic information regarding concrete, reinforced concrete, and constructional engineering generally.

The uses of concrete and steel are at present being accorded the closest possible attention by all interested in building and engineering work. The apathy with which any question appertaining to the application of these materials in modern constructional work was originally met has almost disappeared. Even the scepticism with which our natural conservatism frequently meets innovations in matters of constructional engineering appears at last to have been overcome, as far as reinforced concrete is concerned. The leading members of the technical professions and trades are considering and freely discussing the subject. The professional institutions are giving a large proportion of time to papers and debates on concrete and steel. The foremost technical writers of books and treatises are presenting valuable information on the subject, while numerous journals are according it considerable space. Abroad—on the Continent of Europe and in the United States of America—the literature in all languages on concrete in particular has become extraordinarily extensive. In fact, in this age of strenuous activity, it has become almost a physical impossibility for any one individual to peruse the more important contributions to the questions involved, spread, as they are, over so wide an area, and presented in so many tongues.

With the appearance of this journal, however, there will now be available a reliable digest of the world's latest information on concrete and constructional engineering as applicable to the British reader. In its pages will be found, in a condensed form, all such data as may be relevant and of use in Great Britain and the Imperial Possessions. This journal is intended to serve as an easily accessible guide to what is being done at home and abroad, and will also serve as the medium for the expression of thought and opinion affected, presented by the ablest exponents available on all questions connected with concrete and constructional engineering.

As a pioneer journal on the application of concrete and steel in the British Empire, it is hoped that its pages will not only be of interest and of use to those already directly and indirectly concerned with the subject under review, but that by their advocacy of what is practical and economical in civil and architectural engineering, they will also compel the attention of those who may still be holding aloof from the application of the modern methods of construction dealt with. In fact, this journal should stimulate interest in all appertaining to concrete and steel, and especially in questions relating to their application economically, rapidly and safely.

This journal is intended to be essentially a practical one for architects, engineers and builders, but yet produced in sufficiently popular style to be understood by employers of labour generally, by directors of industrial corporations, by the members of Parliament and local councillors, in fact by all who direct and influence building and civil engineering work in the British Empire, and who should understand the advantages of modern materials and methods.

This journal will enjoy the best expert assistance obtainable, and there will be no parsimony where expenditure is necessary for the presentation of the latest scientific data from pens of undoubted authority.

Every effort will be made by those conducting this journal to present opinions as independently as possible, even if such opinions are at times not so orthodox or so insular as is generally expected by those accustomed to well-trodden paths.

In advocating the extended use of concrete and the application of the most up-to-date principles of constructional engineering, stress will be laid on the absolute importance of using none but the best of materials and work, and as such excellent materials and work are produced by leading British firms, everything possible will be done to further the specification of British material and the employment of British labour. Although no insularity will be observable when useful ideas of foreign origin come under review—and, in fact, the application of such ideas may be energetically advanced—this journal will call attention to any unnecessary use of foreign material or employment of foreign labour, particularly in respect to works carried out under the auspices of the Government and municipalities with the money of the British taxpayer and ratepayer. Those conducting this journal go so far as to consider that on property under the control of Government Departments and public bodies generally, preference should always be given to work and material obtainable within the British Empire; in fact, they hold that where British work and material are obtainable at reasonable prices, nothing else should be utilised by our public authorities.

The various industries associated with constructional engineering and concrete, be they represented by the manufacturers of cement, the producers of structural steel, or the purveyors of special systems of construction, will find in this journal an exponent of the difficulties under which they frequently have to work, to the detriment of good construction, to the disadvantage of the British worker, and to the loss of the State. This journal will, in fact, be a strong supporter of the home industries affected, and it is to be hoped that its efforts may be of some assistance, not only in the advancement of sound and economical work generally, but more particularly of such work as is entirely British.

OUR SPECIAL CONTEMPORARIES.

In the Announcement of this journal we mentioned the extraordinary extent of the current literature on questions regarding the uses of concrete and reinforced concrete. There are very few of the great engineering and building papers at the present moment that do not, almost in every issue, treat of some important point affecting the subject. Even such great contemporaries as "Engineering" and "Engineer" in this country, and "Engineering News" and "Engineering Record" in the United States, the pressure on whose space, owing to the wide range of engineering subjects dealt with, must be enormous, are almost weekly presenting several valuable contributions to the subject.

Speaking generally, we think that over one hundred journals in different parts of the world are giving attention to the uses of concrete and steel in constructional work. Furthermore, we would point out that there are already in existence several journals abroad solely devoted to the problems of concrete and reinforced concrete.

Generally recognised as a specialist journal of primary importance, we believe, is "Beton und Eisen," an Austrian contemporary, edited in Vienna, but since last year published at Berlin. Further, there are published in the German tongue "Zement and Beton" and "Mitteilungen über Zement, Beton und Eisenbetonbau"; in France there is the journal "Le Ciment," and also a journal specially issued for the agents of a well-known proprietary system, "Le Beton Armée"; in Italy the journal "Il Cemento," a cement organ which devotes considerable space to concrete, and the same may be said of "Cement," published in the United States, and "Cement Age"; whilst a journal devoted entirely to the subject is our partial namesake in the United States, "Concrete."

In the initial number of this journal it would not be out of place, perhaps, to congratulate the journals named upon the useful work they have done, and we trust that the relations between this journal and those named may be cordial.

It is certainly a sign of the great progress already made in the application of concrete and reinforced concrete on the Continent and in the United States, that so extensive a contemporary specialist literature should already exist.

THE ROYAL INSTITUTE OF BRITISH ARCHITECTS AND REINFORCED CONCRETE.

We understand that the Royal Institute of British Architects has made arrangements for dealing with reinforced concrete, and that several other technical societies and some of the public authorities have been invited to appoint delegates to a conference on the subject. The Institute is to be congratulated upon this move, which can only be of benefit to both the architectural and engineering professions, and pave the way to a better understanding of certain features of reinforced concrete that should be dealt with on uniform *i.e.*, "standard" lines.

Any suggestions made by the Institute should receive the careful consideration of the Local Government Board, the London County Council, and other municipal authorities who must shortly be framing building regulations to meet the advent of this new system of construction.

We trust that the members of the Sub-Committee will accord due attention to *all* of the many aspects from which the application of reinforced concrete may be regarded, including not only those of strength, but also those of economy, fire resistance, and wear.

INTERNATIONAL CONGRESS OF ARCHITECTS ON STEEL AND REINFORCED CONCRETE CONSTRUCTION.

We observe from the programme of the International Congress of Architects, which will have its next session in our metropolis during the current summer, that one of the subjects that has been selected for discussion is entitled "Steel and Reinforced Concrete Construction," and the subject is to be considered from two aspects, *i.e.*—

(*a*) From its general aspect, and
(*b*) With special reference to æsthetic and hygienic considerations in the case of very high buildings.

No subject could be more appropriate for the consideration of an international congress of architects. With delegates present from the United States—the home of steel construction—and from France and Germany—the homes of reinforced concrete construction—there is sure to be a most instructive presentation of the different aspects of the subject, and it is to be hoped that the foreign visitors in particular will not be shy in giving full particulars of practical experience obtained in their respective countries.

THE FIRE SERVICE AND REINFORCED CONCRETE.

The importance accorded to questions relating to reinforced concrete in all spheres may be gauged, when even the agenda paper of the year's Milan International Fire Service Congress of May next accords the subject a prominent position. This is easily accountable if we remember that fire service questions are becoming more and more a matter of fire prevention to be dealt with by the engineers, architects and surveyors. To apply reinforced concrete without due regard to its fire resistance is a very serious matter, both in respect to safety of life and the protection of property, and the fire service will, no doubt, very plainly state its opinion, with the view of influencing constructional practice and legislation in the interests of the community. The Congress will be under the auspices of the International Fire Service Council, upon which Great Britain is well represented.

CONCRETE AS A FIRE RESISTANT.

Gradually, but very surely, during the past decade it has become generally recognised in Great Britain that concrete lends itself admirably for use in buildings intended to be fire-resisting.

It is, however, a matter of the highest possible importance to all interested in the application of concrete that there should be a greater discrimination than heretofore in the specification of concrete aggregates, where concrete is particularly used on account of its fire-resisting qualities. It has been all too common to generalise the term "concrete," and at the most to differentiate on points of richness.

In future it must, however, be considered an essential as far as the use of concrete in buildings is concerned, and more particularly in respect to concrete floors, walls, and partitions, concrete girder and stanchion encasements, that thought be given to the suitability of the aggregates used in the event of fire.

It has, for instance, now been proved time after time that, however excellent Thames ballast concrete may be for strength and from economic reasons, that Thames ballast concrete as generally used is entirely unsuitable as a fire-resistant. But, of course, for certain classes of work in certain locations, Thames ballast and similar material are the only ones economically available for concrete work, in which case it will be necessary to so deal with the ballast as to possibly reduce its unsuitability.

On the other hand, there can be no doubt that the materials most suitable in concrete aggregates as fire-resistants are those that have already passed through the ordeal of fire, such as clinker, slag, coke breeze, broken stock brick. In fact, if the ordeal of fire has been passed, and there still be some slight porosity, as in the case of clinker, coke breeze, and broken brick, the results are eminently satisfactory.

But, speaking generally, this note is only intended to remind those concerned that where fire resistance is intended, discrimination in aggregates is essential, otherwise the whole trend towards concrete construction may, say, after some accident, be seriously hampered by legislative protective measures of undue severity. Those interested in reinforced concrete are particularly recommended to accord attention to this point, as the haphazard description of all reinforced concrete construction being fire-resisting requires modification. Reinforced concrete construction is certainly fire-resisting if the aggregate is suitable, if the cement be of British standard quality, and if, further, the metal parts are well protected against the impingement of flame. But not otherwise.

FIRE TESTS WITH CONCRETE.

The question of the exact fire resistance of concrete, and reinforced concrete in particular, is not yet ripe for final standardisation or even for the definition of permanent rules, but steps are being actively taken, both with us and in the United States of America, to arrive at conclusions of lasting value. In the United States, the National Fire Protection Association has been undertaking certain experiments of the greatest importance, and similarly the British Fire Prevention Committee in this country is investigating both the question of the fire resistance of concrete and reinforced concrete in a very thorough manner.

The results of these tests will be recorded from time to time in this journal, and articles will also be presented setting forth the various views existing as to fire protective control of concrete constructional work by local authorities, and by insurance offices.

FICTITIOUS PORTLAND CEMENT.

A very interesting pamphlet has been issued under the title "A Modern Danger," pointing out the great risks that are being run by the use of natural cement, where Portland cement, *i.e.*, the artificial product, should be employed It is of the utmost importance to engineers and architects, and to all contractors, that they should not be made the victims of the fraudulent practices adopted by many cement merchants or agents, who import an unreliable natural cement from abroad, and sell it under a fictitious label as Portland cement.

We grant that, occasionally, one meets with a small quantity of natural cement of fair quality, but, as a rule, natural cement is entirely unreliable in quality and is distinctly dangerous to use, and the comparative analysis between British Portland cement and Belgian natural cement, from some tests by Mr. R. H. Harry Stanger, official examiner to the Admiralty, only too plainly shows how unwise it is to use this natural product.

Every possible subterfuge has been used by certain importers to foist natural cement upon the professions and contractors concerned. The Merchandise Marks Act is, unfortunately, not sufficiently explicit as to stop the importation under fictitious labels. But the booklet actually speaks of cases where this natural cement is bagged in double bags, the outer one indicating the true character of the material, whilst the inner one has some fictitious description and marks on it. The moment the Customs are passed, the outer cover is ripped off and the inner one only used to gull the buyer.

The booklet proposes certain remedies, and those which are of primary importance to engineers and architects are that, in specifying, it should be clearly stated that the Portland cement required is to be an artificial Portland cement of British manufacture; and, secondly, that the bags should bear the full name of well-known British manufacturers. Strict compliance with the specific gravity and Chatelier tests, as set out in the British Standard Specifications, is also strongly recommended.

These suggested safeguards are very well as far as they go, and no doubt efforts will be made by the industry primarily concerned to obtain a reading of the Merchandise Marks Act that does not encourage, as is the case at present, the import of material under fraudulent descriptions.

But what is really required, not only in respect to cement, but many other of the materials employed on engineering and building works, is that there should be an Act equivalent to the Food and Drugs Act, which will make it an offence, easily ascertainable and rapidly punishable, to obtain money under the false pretence of selling a building material that does not fulfil its description.

It should certainly be a matter of the utmost importance to the professions concerned, as well as to the leading contractors, to have a stop put to the selling of building materials under fictitious labels.

THE ADVENT OF THE CONCRETE AGE

By Lieut.-Colonel J. WINN, R.E., A.Inst.C.E.

(Late Instructor in Construction, School of Military Engineering, Chatham.)

This article is intended to review the development of concrete as an important factor in constructional engineering and the structural works of civilisation generally. Most of the illustrations in the current issue of this journal testify to the author's arguments, and serve as examples of some of the many uses of concrete mentioned by him.—ED.

WE are accustomed to hear of the "Stone Age," the "Bronze Age," leading up to the "Iron Age," which in the last century merged into the "Steel Age," terms finding their origin in the materials most in evidence during and characterising the periods indicated. There is little doubt that, when our descendants review the past and speak of the dawn of the twentieth century, especially in its relation to structural engineering, the term "Concrete Age" will not be inappropriate.

Lime concrete has had its place in construction through many centuries, and the excellent character of the material is evidenced by many an old castle, whose rubble masonry—virtually a rough concrete—testifies to the thoroughness of the work executed by the builders of a bygone day.

The concrete of which we speak as being specially characteristic of the present day is of a different type, and owes its introduction largely to the invention of cement composed of chalk and clay, suggested in the middle of the nineteenth century by Sir Charles Pasley, of the Royal Engineers. This suggestion led to the birth of the Portland cement industry, which, in a measure, has revolutionised engineering methods, and made possible the execution of works previously unattempted.

Lime concrete, as we have seen, had been used—and used extensively—for ages, but there had always been an uncertainty as to its composition and strength, limiting its use and restricting its employment to a comparatively narrow field.

But with the introduction of cement produced under conditions permitting the observance of great accuracy in the porportions of its constituents, and consequently capable of inspiring confidence, the employment of concrete became more general, and its use has developed in so marked a degree that it is almost impossible to think of any large engineering work into which it does not enter.

The demand for Portland cement speedily brought into being many works for its manufacture. The Medway and the lower reaches of the Thames, where chalk and clay were in convenient juxtaposition, soon gave evidence that a new industry had arisen in Kent and Essex, Germany and Belgium and the United States rapidly followed suit.

The fact that large undertakings could be carried out with comparatively unskilled labour, the adaptability of a mixture of broken stone or gravel, sand and cement, to almost any situation, and the consequent cheapness of the work, have conduced to the popularity of concrete, and, since the economy resulting from its use has been further increased by the employment of mechanical mixers, concrete has become predominant in almost all structural works of importance.

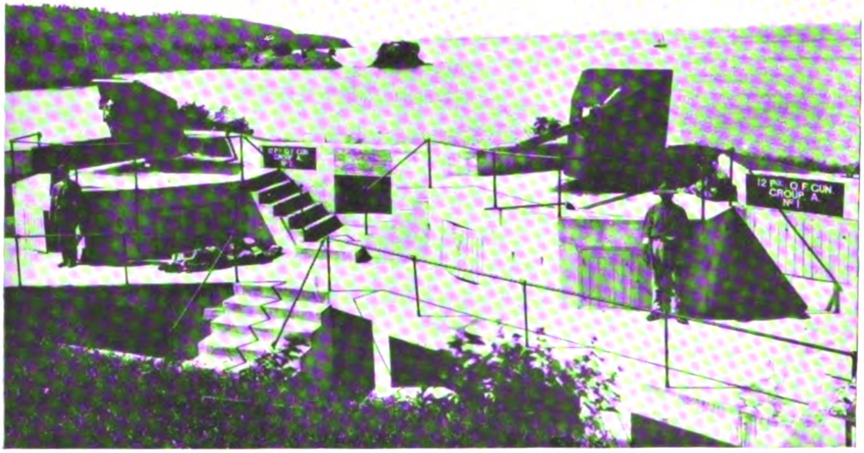


FIG. 1. CONCRETE FOR MILITARY WORKS.
A Modern Fort.

ITS EARLY USES.

At first the use of concrete was chiefly confined to foundations, but in process of time its usefulness in the form of backing for dock and sea walls became recognised, and already, in its early days, many thousands of yards were used thus in the extension works of the Naval Dockyard at Chatham.

Experiments carried out in connection with these works showed that concrete was worthy of a more important place in engineering construction than as a mere backing for masonry and brickwork, and retaining walls were soon afterwards built entirely of concrete. (*See* Fig. 1.)

In the construction of such works, not only were the faces exposed to the fire of a possible enemy, built of mass-concrete, but the walls and roofs (generally in the form of arches) of the casemates were also of the same material, and in some cases the roofs of emplacements were formed of flat slabs of considerable thickness supported on iron or steel joists.

It must not be supposed that all engineers regarded concrete with the same confidence, and the carrying away of one or two coast protection works aroused suspicions that it was not suited for sea-walls, breakwaters, jetties, and kindred structures. It was afterwards shown that the failures in question were due, not to the effect of the salt-water upon the cement, but to other causes, the chief of these probably being that the voids in the aggregate had not been properly filled with sand and cement; or that, when placed in position, the concrete had not been adequately rammed, a process which is found to reduce its bulk by as much as 10 per cent., and to increase its compactness in equal proportion. Unless concrete is properly proportioned and consolidated, it is apparent that the dynamic action of the waves will produce immense air pressure in the cavities, sufficient to occasion a disruptive force capable of wrecking the work in which the concrete is employed.

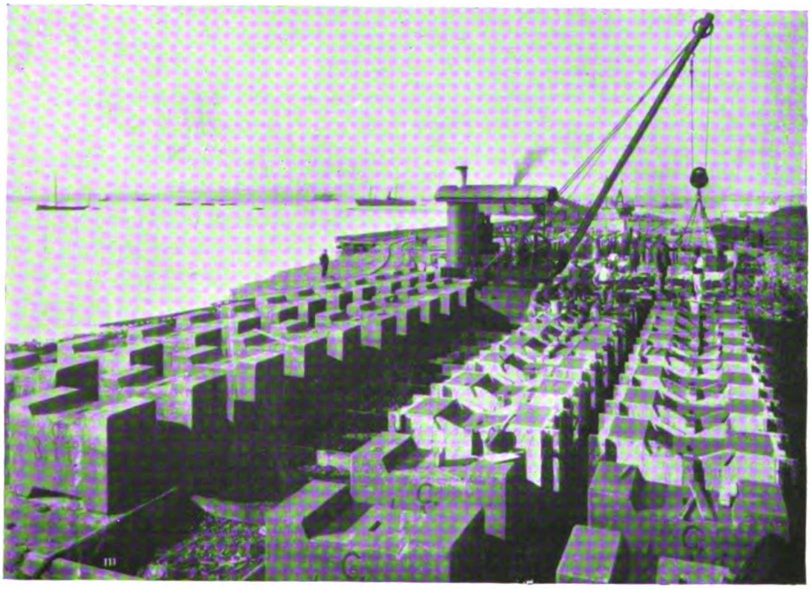


FIG. 2. CONCRETE FOR GOVERNMENT HARBOUR WORKS.
A Concrete-Block Yard.

There is little doubt also that, owing to the inadequate appliances used in some of the earlier coast defence works, a great deal of the cement was washed away in under-water construction, and in some cases it was found that in consequence the remaining mass was little better than the gravel that formed the aggregate.

Whatever the causes may have been, there is no doubt that the failures mentioned gave concrete a set-back for a time in works of this description, but with successive improvements in the quality of the cement, a better understanding of the necessity for consolidation, and better knowledge as to the manner in which this could be ensured, the great advantages of concrete reasserted themselves, and the failures proved valuable lessons and tended to still further development in the use of this material.

ITS STEADY ADVANCE.

As time went by the quality of concrete was steadily and surely improved, and the sphere of its usefulness correspondingly increased; its resistance to percolation and compression, when properly made, opened up a field in the direction of reservoir construction, and not only was it extensively used in America for the cores of earth dams, but many dams have been constructed entirely of concrete or of concrete with a facing of masonry. It should be pointed out, however, that concrete core walls have not always been successful, owing to insufficient care in guarding against percolation.

It is interesting to remember that, although Portland cement concrete has been generally used in dam construction, a remarkable exception is to be found in a work of this class recently executed at Torpantau, in Wales. This dam known as the Upper Neuadd Dam, was built of hydraulic lime concrete. (*See* p. 7.)

Before passing on to other developments of practice, the adaptability of concrete for being moulded into masses of any required form and dimension should be mentioned. *See* Fig. 2.) An instance is furnished by the huge blocks of forty tons' weight which are being moulded and built into the Admiralty Harbour Works at Dover, a method of construction rendering the piers and breakwater specially suitable for resisting the impact of the waves.

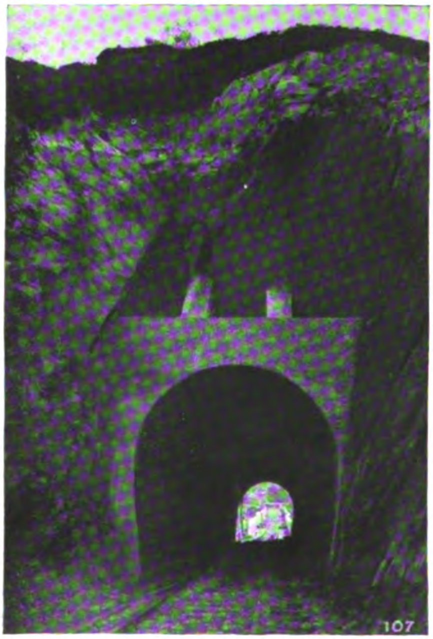


FIG. 3. CONCRETE FOR RAILWAY WORK.
Tunnel on the North British Railway

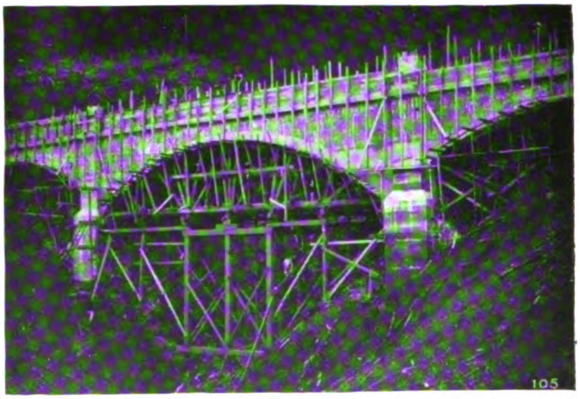
As already stated, the resistance of concrete to compression has increased as the quality of cement has been improved, so that it is now found by many experiments, that the resistance to crushing of 5 to 1 concrete, even at the end of one month, approximates to 200 tons per square foot.

When the significance of this fact was appreciated, engineers began to employ concrete for forms of construction other than the massive works which had hitherto been the sphere of its usefulness.

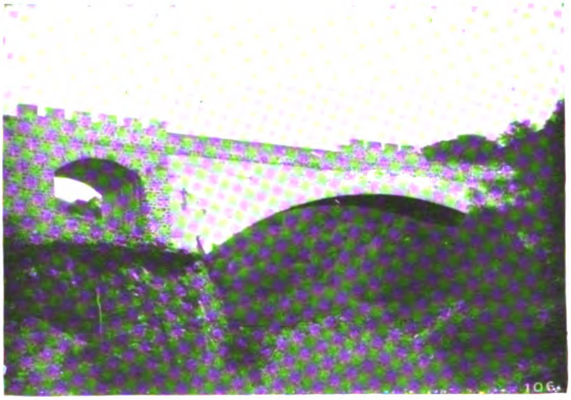
Continental engineers began to use it for bridge construction, and arches (generally hinged), with spans of as much as 160 ft. were erected, at a cost comparing most favourably with masonry arches of the same class, thus enabling bridges to be constructed in country districts, hardly able to afford the outlay necessary for building bridges of stone, brick or steel.

The engineers of this country were somewhat slower in adopting concrete for work of this description, and even on the Continent it was not used for railway work, fears being entertained that the vibration which is inseparable from high speeds and heavy loads would tend to disintegrate the material. Still, its advantages for work where masons are few, and transport is difficult, were among the considerations that induced the engineers of the North British Railway to adopt concrete almost exclusively in the extension of their line from Fort William to Mallaig. (*See* Fig. 3.) There we find viaducts (foundation, piers, arches, walls), bridges up to 126 ft. span, retaining walls, sea-walls, platforms, and even station buildings, all of concrete, the most striking example being the Glenfinnan Viaduct. This structure is 90 ft. high, with nineteen arches of 50 ft. span, and was built on a curve at a place where the line was on a gradient. (*See* Fig. 10.)

The line from Fort William to Fort Augustus also affords -examples of concrete bridges, and many are to be found on the new branches in Lanarkshire and elsewhere in Scotland. (*See* Figs. 4 and 5.)



Bridge on the Fort Augustus Line.



Bridge on the Barrodale Railway.

FIGS. 4 AND 5. CONCRETE BRIDGES.

In England the Holsworthy Viaduct, on the London and South-Western Railway, and the Cannington Viaduct, on the Axminster and Lyme Regis Light Railway, are entirely of concrete, the former built on the block system, and the latter of mass-concrete The cost of these works was considerably less than if they had been executed in stone or brick, in view of the local conditions prevailing.

Other viaducts of the same material are in course of construction at the present time, and it is a matter of common knowledge that the original proposal for the Vauxhall Bridge was that it should have concrete arches.

All these instances show that concrete is growing in favour for work on which it was not previously employed, this partiality being still more marked in America.

ITS USE IN CONNECTION WITH IRON AND STEEL.

But an even more remarkable development in the use of concrete in combination with iron and steel has characterised engineering enterprises during the last few years, and opened up a field of usefulness which seems without limit.

It has already been noticed that the quality of Portland cement has been continuously improved to meet the requirements of engineers who have demanded the highest grades, in view of the importance of the works to be carried out. Fine grinding was early recognised as essential, and English cement, by leading makers, of course, leaves nothing to be desired in this respect.

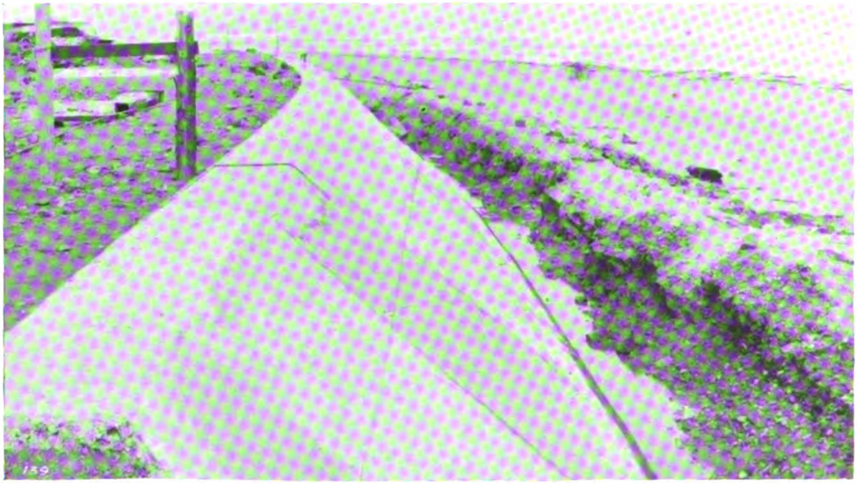


Fig. 6. Reinforced Concrete for Shore Protection.
Esplanade, West Hartlepool.

The tensile strength of cement has been increased, but must necessarily be comparatively low in contradistinction to its compressive resistance, owing to the very nature of the material.

Consequently, concrete has not been used in situations where it would be exposed to tensile strains. But the introduction of steel as reinforcement has supplied the very quality that concrete lacks in itself, and now we find the blending of these two materials has given a fresh impulse to the employment of concrete in all kinds of structures, including floors, beams, arches, piles, walls, partitions, pipes, aqueducts, bridges of large spans, tall chimneys, lighthouses—all these being executed entirely in concrete reinforced with steel.

It would be impossible in the space of a short article to refer to all the varied uses to which reinforced concrete has been applied, and to trace the development of this new form of construction.

As mentioned in the earlier part of this article, roofs of concrete supported on steel girders were employed long ago in fortifications, but these were of very massive character, designed more for protection from gun-fire than as mere coverings, and in them the concrete had not been arranged so as to take all the compression and the steel all the tension, which is the principle underlying the design of concrete-steel structures. Floors had also been made of concrete in the form of arches or slabs between steel girders, but in these reliance was placed entirely on the strength of the girders, the concrete being treated as dead-weight.

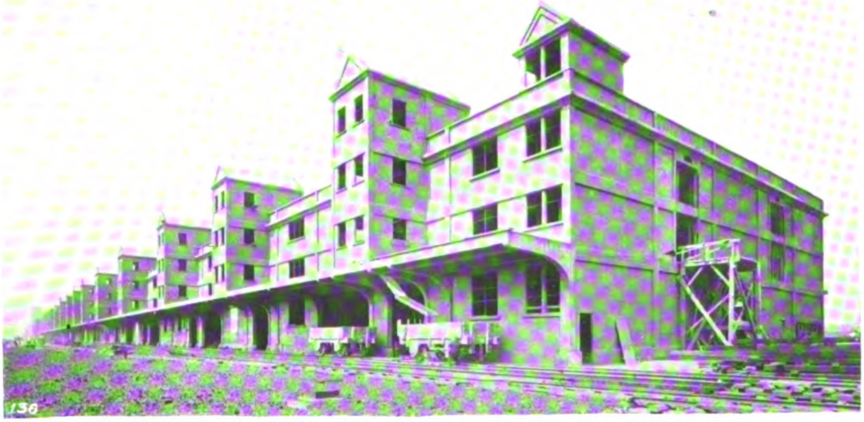


FIG. 7. REINFORCED CONCRETE FOR WAREHOUSE CONSTRUCTION.
New Transit Sheds, Manchester.

REINFORCED CONCRETE.

It was not until comparatively recent years that the idea was conceived of embedding the steel in the concrete, so that each material could take its share in resistance, forming, as it were, a new material. This idea was developed first by Continental engineers, and later by those in America. Still more recently it has been taken up by British engineers and architects, who, however, do not yet seem to have adopted this excellent form of construction to the same extent as their foreign brethren.

In addition to the other valuable properties of concrete already mentioned, there is to be added its great resistance to the effects of fire if of suitable aggregate, and when combined with a small amount of steel to supply its deficiency in resisting tensile strains, its suitability for the construction of buildings of all kinds becomes apparent.

Immense warehouses (*see* Fig. 7), depôts, cold storage sheds, drill halls, and factories have been built, and are now being made, entirely of this reinforced concrete, and as, owing to the introduction of the steel, the walls, floors, roofs and other details need no longer be of massive character, great economy is possible. It is no uncommon thing to find walls 60 ft. high of but 4 in. in thicknesss between the piers which support the roof trusses of a building, and as the enveloping concrete preserves the encased steel from corrosion, we find each material communicating to the other the quality it needs to ensure endurance. For, as the steel supplies the resistance to tension which the concrete lacks, so does the concrete supply that protection from climatic influences which are so deleterious to the steel. More than this, the concrete provides the steel with a protection from the effects of fire, which has proved so disastrous to unprotected steel-framed buildings in days gone by, and to which all unprotected steel work is exposed to this day.

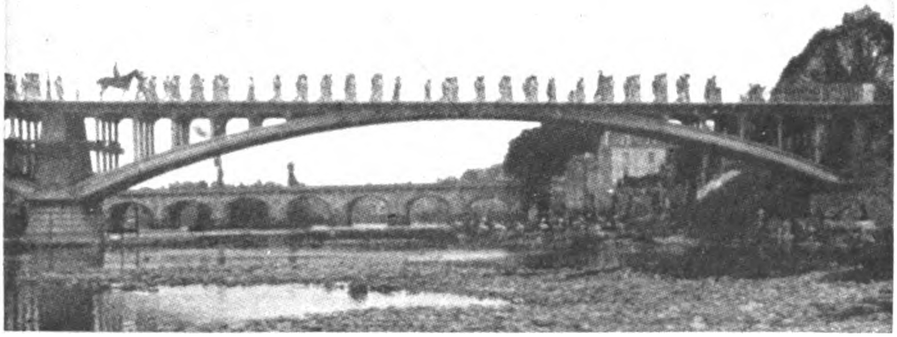


FIG. 8. REINFORCED CONCRETE BRIDGES (IN FRANCE).

Insurance associations recognise this advantage of reinforced concrete structures, and encourage their introduction by allowing them to be classified as ' standard " fire-resisting buildings if designed in compliance with certain rules.

THE ECONOMY OF REINFORCED CONCRETE.

To give an instance of the economy of material by using reinforced concrete in a chimney stack 141 ft. high, recently completed in America, it may be mentioned that the outer shell was only 6 in. thick at the ground level, and 5 in. thick at the top. Its construction occupied sixty days, and the maximum pressure on the ground was only two tons to the square foot.

Warehouses have been entirely constructed of reinforced concrete at a cost not more than that of the steel alone that would have been required for the erection of a similar building by the old method of construction. Further, as such buildings are fire-resisting in a high degree, the insurance premiums have been correspondingly low where certain safeguards have been observed, and it must be remembered that the charge for maintenance is practically nil.

That reinforced concrete is capable of withstanding heavy shocks has been demonstrated by the fact that piles made of it have been driven without injury; large wharves, alongside which enormous ships are berthed, are constructed of it, as also sea protection works. (*See* Fig. 6.)

That it is suitable for railway and road bridges is shown by numerous examples on the Continent of spans from 167 ft. and downwards, the scantlings being considerably less than those required for a plain concrete bridge, as reinforced concrete is capable of resisting tensile strains. (*See* Fig. 8).

That it is suitable for reservoirs is clearly shown by the case of a stand-pipe with a head of 50 ft. and diameter of 20 ft., only 6 in. thick at the bottom of the wall. Miles of sewers, with diameters of 6 ft. and above, have been made of it, and pipes of smaller diameters are used for water supply under considerable heads. (*See* p. 7 and Fig. 9.) Private houses, churches, theatres, and public buildings of all kinds have been entirely executed in reinforced concrete, and the variety of uses to which the new material is being put on all hands is one of the most striking features of present-day structural practice.

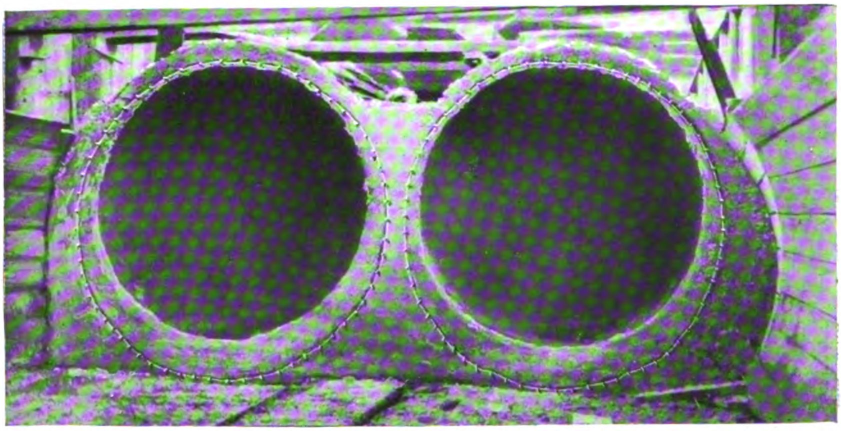


FIG. 9. REINFORCED CONCRETE CONDUITS (BALTIMORE, U.S.A.).

It must be confessed that the engineers and architects of this country have not availed themselves of this combination so fully as could be wished.

DIFFICULTIES TO BE OVERCOME.

Among the reasons for this backwardness, the foremost is probably the conservatism which characterises us as a people, and the hesitation to adopt new methods without exhaustive trial, but among architects the restrictions of building bye-laws have undoubtedly hindered its employment, for these regulations, frequently drafted by councils who know nothing of the capabilities of the new material, and often under the advice of someone who has no experience in its use, still insist that all walls of concrete must be of certain dimensions, based on the properties of plain concrete, and have failed to recognise that the incorporation of the steel has introduced absolutely new conditions, and communicated a strength unknown before.

These restrictions obviously preclude the economy of material, which the adoption of proper dimensions ensures, and, as the success of reinforced concrete construction depends not only upon the proper design for each item, but upon very careful supervision in its execution, the extra time needed in superintendance may, in the estimation of some architects, outweigh the other advantages to be gained.

The saving in the cost of reinforced concrete, as compared with other usual types of construction, depends largely upon the design of the shuttering, centring and moulds generally, and upon the degree to which these can be utilised over and over again. If such auxiliaries can be so designed to ensure repeated use, a considerable saving will result, as the materials are in themselves inexpensive, and comparatively unskilled labour can be employed as long as supervision is constant and efficient. The time of actual construction compares favourably with that required for other materials.

It has to be recognised that some failures which have occurred may have militated against the more extensive adoption of reinforced concrete in the British Isles, making some doubt the wisdom of its use. Upon investigation, however, it will be found that such failures have not been due to any inherent weakness of the material, but either to faulty design or faulty execution.

In some cases it has been found that weak centring, deficient in rigidity, has been used, or that the centring has been removed before the work had properly set. In other cases, absolute ignorance of the principles underlying the use of the material has been apparent, and in still other cases the quality and proportions of the constituents have been such as to invite disaster. Failures of the kind are *never* found where the requirements of the case are properly understood and provided for.

In spite of a few failures, however, the employment of concrete in this form is gaining ground, and will undoubtedly continue to do so; and, as suggested at the commencement of this article, its general adoption marks an epoch in what may well be entitled the "Concrete Age."

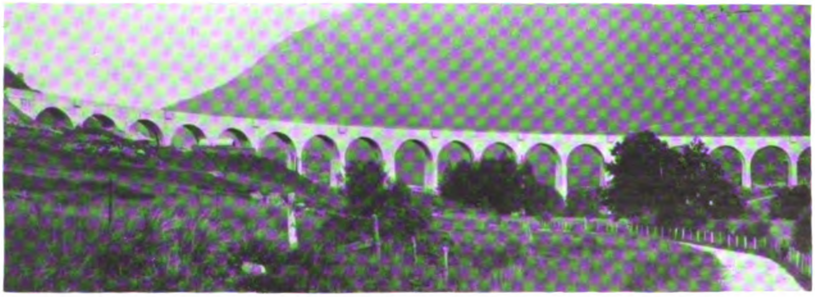


FIG. 10. CONCRETE FOR VIADUCTS.
The Glenfinnan Viaduct.

STEEL SKELETON CONSTRUCTION AND THE LONDON BUILDING ACT.

By
W. NOBLE
TWELVETREES,
M.I.Mech.E.,
Author of "Structural Iron and Steel" and "Concrete Steel."

The unfortunate manner in which the advantages of steel skeleton construction are discounted by certain out-of-date requirements of the London Building Act of 1894, is obviously detrimental to sound and economical building in the Metropolis. The author of the following article indicates both the technical and economic anomaly of the present state of affairs, for which a remedy should be found at the earliest possible moment. - ED.

During the second half of last century, and especially since the advent of mild steel, British architects have gradually accustomed themselves to the employment of iron and steel columns built separately into walls for the support of girders and joists, and of girders and joists loosely set in place to carry floors and curtain walls. But until recent times such members were rarely connected in a really satisfactory manner, and it is only within the last few years that they have been applied systematically and in accordance with the excellent example set by our American cousins.

At last, however, architects are fully awakened to the merits of skeleton building construction, but now find to their annoyance that, during the period of somnolence, building regulations have been enacted effectually barring the way of progress. Clearly, those who framed such laws, and the London Building Act of 1894 is one of the worst, had forgotten nothing of old traditions and had learned nothing of newer methods. The result was an Act at least fifty years behind the most advanced architectural practice, and a century behind engineering practice. We fear, however, that at the time the Act was passed it was not very far from representing the practice of average architects, and that the profession cannot be entirely absolved from blame in permitting the enactment of so unsatisfactory a measure.

Still, the time of distrust has passed away, and architects are now prepared to introduce steel as a recognised and legitimate material of construction, and not as one to be used apologetically and as an unorthodox substitute for timber or brick.

The strength of the feeling is shown by the recent recommendations of the Royal Institute of British Architects that steel skeleton construction should be officially recognised in the revision of the London Building Act, and by the erection—despite the handicap created by the clauses of the Act—in the Metropolis of various steel-framed buildings, among the best-known being the

Savoy Hotel Extension and the Ritz Hotel. The British Westinghouse Works and the new Midland Hotel, both in Manchester, are further examples of the same principle. All these buildings were designed so that the steel skeleton should be capable of carrying the entire dead weight of the walls, floors and roof, in addition to the live load, and the stresses due to wind pressure.

As to the Savoy Hotel Extension, a building familiar to most of our readers, in which all columns, girders, and floor joists are connected so as to form a genuine example of framed construction. Messrs. Colcutt and Hamp were the architects.

A better illustration of skeleton construction is, however, afforded by the new Ritz Hotel, in Piccadilly, in respect to which Messrs. Mewes and Davis act as architects, in conjunction with Mr. Bishop, of the hotel company's staff. This building includes a skeleton of steel capable of carrying the whole dead weight of the walls, floors and roof, in addition to heavy live loads. With the object of keeping the building entirely within the boundaries of the site, cantilever foundations were adopted for some of the columns. The steel framing is encased in concrete, and floors and roofs are of concrete reinforced on the "Columbian" system, and thus the primary features of the building are of fire-resisting construction throughout. Notwithstanding the capability of the steel skeleton for supporting the whole of the loads without any help from the brick walls, the architects and contractors were compelled to comply with the letter of the London Building Act. The unnecessarily—nay, ridiculously—heavy character of the brick and stone masonry is made clear by Figs. 2 to 4.

Outside the Metropolis the most remarkable example of steel frame construction hitherto completed in this country is afforded by the works and offices of the British Westinghouse Company, at Trafford Park, Manchester, built from designs prepared by the company's architect. The establishment includes nine buildings in all, covering an area of some 55 acres. All the buildings consist of massive steel framework, with brick-enclosing walls 18 in. and 23 in. thick in the workshops, and somewhat thicker in the office building. Thus it will be seen that the Manchester building regulations limit the scope of structural engineers as well as the universally condemned Act applying to the Metropolis.

The new Midland Hotel, Manchester, covers an area of nearly two acres, and is open on all sides to the public streets. The building is ten stories high, and contains 480 rooms, including rooms for meetings, concerts and balls, in addition to the usual apartments of a hotel. The foundations are of exceptional strength, and excavations were carried down to bed rock, in some places to a depth of 30 ft. below street level. From the foundations a complete steel skeleton was erected, and this framework was afterwards encased in masonry. The building was erected from the designs of Mr. Charles Trubshaw.

Notwithstanding the strength of the steel skeleton and the fact that the walls have no duty to perform from a constructional standpoint, and are merely useful for the convenience and comfort of inmates, the provisions of the London Building Act made it necessary that the first two of the buildings mentioned above should have walls just as thick as if they included no steel, and were really required to sustain their own weight and that of the superincumbent loads.

In view of a restriction so vexatious and oppressive it may well be wondered why steel framework was used at all. The answer is possibly to be found in the desire of the owners to have buildings of the most improved type, exemplifying throughout the best methods of fire-resisting construction, and necessitating in any event a network of steel members on each floor, as well as some interior columns for the support of floor loads. Consequently, the additional cost of making the system of steelwork thoroughly complete would probably be well repaid by the assurance given that the metal members were employed in a scientific manner, rendering the buildings far more stable than they could be if relying upon the disjointed association of steel and brick permitted and unintentionally encouraged by the London Building Act.

Nevertheless, that code has imposed heavy and perfectly irrational burdens upon the owners of these buildings, and of hundreds more in London, without providing any guarantee of greater security. In other cases, to be cited later, by discouraging the use of steel in a correct manner and permitting its use in an incorrect manner, the Act has probably tended to reduce rather than to increase the stability of buildings.

So far as the thickness of walls is concerned, the clauses of the Act of 1894 are practically the same as those contained in the Metropolitan Buildings Act of 1855, drawn up before mild steel was known, and when wrought-iron could only be produced in the old-fashioned puddling forge with a maximum capacity of 5 cwt., and laboriously fashioned in tiny "blooms" of 70 lb. to 80 lb. each.

It is literally astounding that the most essential clauses of a building law passed only twelve years back should have been allowed to perpetuate the restrictions that were already obsolete half a century ago. But the mischief being done, we have to see that amends are made at the earliest possible moment.

To show the practical hardship inflicted by the present regulations, let us take the case of a "Building of the Warehouse Class," without, however, regarding the question of cubical contents. We will assume the height to be 120 ft., the length 100 ft., and the width 50 ft., taking the height of the stories at the average of 10 ft. each to simplify the following approximate calculation.

Then, according to the First Schedule of the Act, the external and party walls shall not be of less thickness than :—One story, 39 in.; next two stories, 35 in.; next two stories, 30½ in.; next three stories, 26 in.; for the rest of its height below the topmost two stories, 22 in.; remainder, 17½ in.

Let us compare these measurements with the dimensions suggested in Appendix B to the recommendations of the Royal Institute of British Architects for the revision of the London Building Act.* Referring to skeleton buildings, paragraph (5) of the Appendix is to the effect that: "No enclosing wall of the building shall be of less thickness than 8½ in. for the topmost 20 ft. of its height, nor less than 13 in. in thickness for the remainder of its height below such topmost 20 ft., provided that window backs may, in all cases, be 8½ in. in thickness."

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* Journal, Royal Institute of British Architects, Vol. XI., No. 7.

As in paragraph (2) of the same appendix, it is proposed that all pillars shall be cased to the extent of 8½ in. thick towards the exterior of the building, and 4½ in. thick on all other surfaces, the space occupied by the walls will be increased by a certain number of piers, for which suitable allowance should be made.

With the foregoing data we can make a rough comparison of the space occupied by walls in accordance with the Act, and with the suggestions of the Royal Institute of British Architects.

Without taking into account the spaces occupied by partition walls, staircases, lift wells, and other interior details, the position of things is approximately as shown in the following table, and as graphically represented by the half-plans and sections in Fig. 1.

Table I.—Reduction of Floor Areas by Thin Walls as proposed for Skeleton Buildings by the Royal Institute of British Architects, and Thick Walls as required by the London Building Act, 1894. (Approximately calculated by a 12-story building, 100 ft. long by 50 ft. wide.)

Floor No.	Gross Area. (A).	Net Area with Thin Walls. (B).	Net Area with Thick Walls. (C).	Area gained by Thin Walls. (B—C).
	sq. ft.	sq. ft.	sq. ft.	sq. ft.
1	5,000	4,680	4,065	615
2	5,000	4,680	4,165	515
3	5,000	4,680	4,165	515
4	5,000	4,680	4,270	410
5	5,000	4,680	4,270	410
6	5,000	4,680	4,390	290
7	5,000	4,680	4,390	290
8	5,000	4,680	4,390	290
9	5,000	4,680	4,470	210
10	5,000	4,680	4,470	210
11	5,000	4,780	4,570	210
12	5,000	4,780	4,570	210
Total ..	60,000	56,360	52,185	4,175

From this table it is clear that more than 13 per cent. of the gross area of the building is occupied by the massive walls demanded by the London Building Act, as against about 6 per cent. by the walls of the thickness proposed by the Royal Institute of British Architects. Even making an allowance of 175 square feet for the space taken up by steel columns and their enclosing brickwork, the percentage in the case of the building with thin walls is only increased to about 6·4 per cent. Consequently, the saving due to thin walls is over 6·6 per cent., or 4,000 square feet of floor space.

To realise what this means to the owner, it is only necessary to consider the additional rental value of a building such as we have suggested when let out in suites of offices.

By taking the square roots of the areas gained, as given in Table I., we can readily obtain the size of the apartment that can be added on each floor, and, by the sub-division of the areas, the number and sizes of the extra rooms on each floor. Of course, for the estimate to be correct, deduction should be made for the thickness of the necessary partition walls, but this would not make much difference in the results, and in Table II. such measurements have not been taken into account. The first column indicates the floors, commencing at ground level, columns 2 and 3 show the accommodation gained on the basis of one room per floor, and columns 4 and 5 show the additional accommodation on the basis of two rooms per floor.

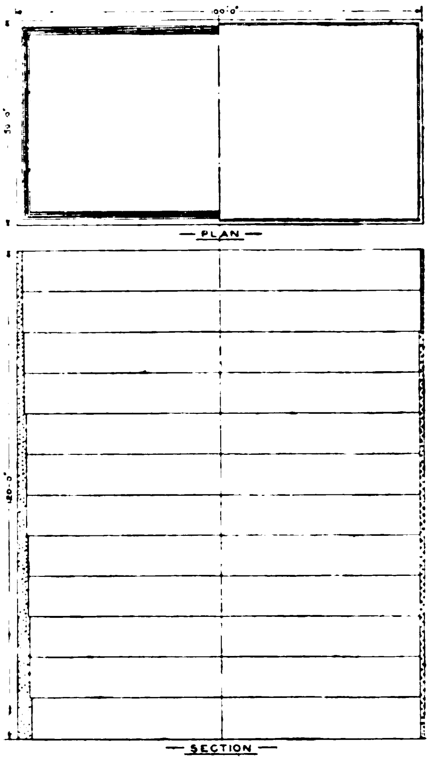


FIG. 1. DIAGRAM ILLUSTRATING TABLE I.

TABLE II. ADDITIONAL ROOMS RENDERED POSSIBLE BY THE ADOPTION OF THE WALL THICKNESSES PROPOSED FOR SKELETON BUILDINGS BY THE ROYAL INSTITUTE OF BRITISH ARCHITECTS INSTEAD OF THOSE REQUIRED BY THE LONDON BUILDING ACT, 1894. (APPROXIMATELY CALCULATED FOR A 12-STORY BUILDING 100 FT. LONG BY 50 FT. WIDE.)

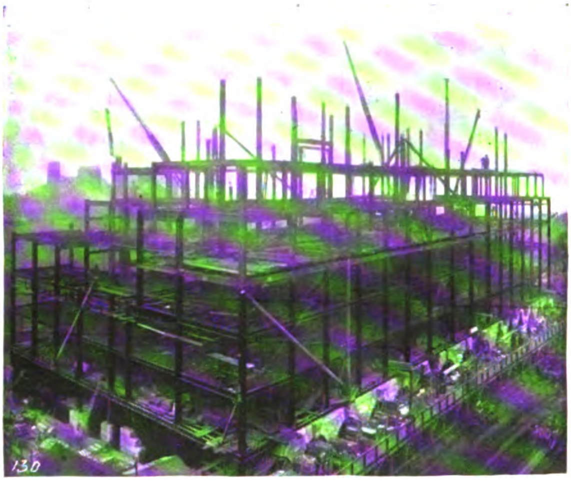
Floor No.	Rooms Gained.			Rooms Gained (Alternative).		
	No. per Floor.	Size.		No. per Floor.	Size.	
		ft.	in.		ft.	in.
1	1	24	9 sq.	2	17	6 sq.
2	1	22	8 ,,	2	16	0 ,,
3	1	22	8 ,,	2	16	0 ,,
4	1	20	3 ,,	2	14	4 ,,
5	1	20	3 ,,	2	14	4 ,,
6	1	17	0 ,,	2	12	0 ,,
7	1	17	0 ,,	2	12	0 ,,
8	1	17	0 ,,	2	12	0 ,,
9	1	14	6 ,,	2	10	3 ,,
10	1	14	6 ,,	2	10	3 ,,
11	1	14	6 ,,	2	10	3 ,,
12	1	14	6 ,,	2	10	3 ,,

In a populous city such as London, the rental value per room for professional or business purposes may be put at the average of £30 per annum for rooms of the sizes in column 5 of Table II. Then, the twenty-four additional offices rendered available should bring in £720 a year, equivalent to five per cent. on a capital expenditure of £14,400.

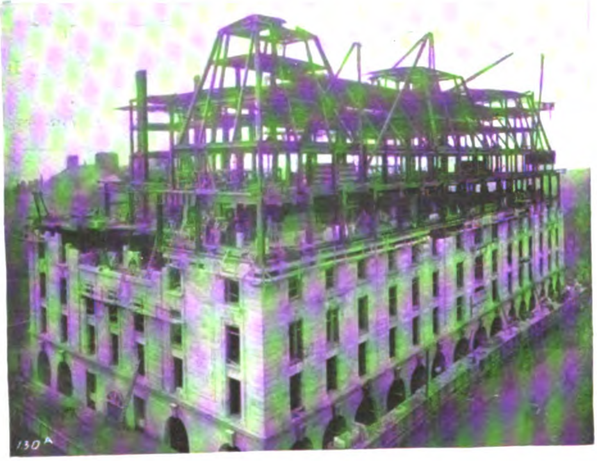
The augmented earning power of the building would be secured, not only without corresponding expenditure, but concurrently with a very considerable saving of materials and wages. How great this saving would be must obviously depend upon the proportion of window area to wall surface, and we need not occupy space by a purely hypothetical estimate which could not be generally applicable.

Although the foregoing figures are merely approximate, they serve the purpose of showing how strong is the case from the owner's standpoint for the exemption of skeleton building construction from the baleful effects of the early Victorian clauses so carefully preserved in the London Building Act of 1894.

But there are other reasons why this Act should be revised so as to make progress in architectural practice economically practicable. Of these, we mention two of the most important. The first is that, by permitting architects to calculate upon the undoubted strength of steel, instead of compelling them to act as if it had no strength whatever, better building construction would naturally



The steel frame in course of erection.



The steel frame being enclosed in masonry.

FIGS. 2 AND 3. THE RITZ HOTEL, LONDON.

follow. If the law requires the architect to think that massive brick walls will cover all sins against the canons of steel construction, there is no encouragement for him to connect up iron and steel members, employed for convenience, into a rigid framework, and there is a direct incentive to the disjointed insertion of stanchions and beams in such a way as to constitute a source of possible danger. Two specific cases will serve to make clear this point. One is furnished by the collapse of the floors during the construction of a large office building, owing to the insecure support of the main girders. If these members

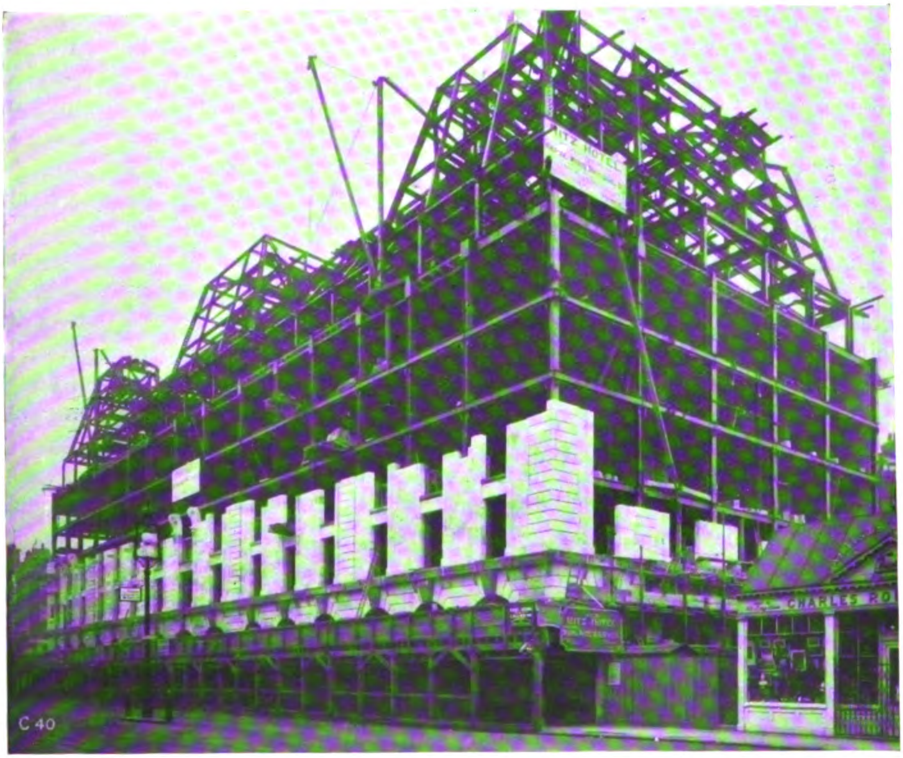


FIG. 4. THE RITZ HOTEL AS AN EXAMPLE OF STEEL FRAME BUILDING IN LONDON.

had been incorporated into a properly-designed framework, the disaster could never have occurred. The other is afforded by a far less alarming, but equally significant, development within the knowledge of the writer. An architect desired to support the bay window construction in the upper portion of a building having a shop on the ground floor. Over the shop front was a steel girder acting as a bressummer, and to this steel cantilever brackets had been fixed to carry the projecting upper part of the building. After the work had been carried to a certain height, the architect was somewhat concerned to find indications of settlement, and very wisely decided to call in the aid of a consulting engineer.

Examination showed that the cantilever brackets were perfectly secure, but that the girder over the shop front had slightly rotated on its longitudinal axis, owing to the leverage exercised by the weight of the brickwork at the end of the brackets. The remedy was obvious, and, being applied in time, no serious consequences ensued. But the moral is that building regulations exercising no control over the proper fixing of steel members do not really afford the protection intended, however thick the brickwork may be.

The two examples quoted show that by recognising the properties of steel, by permitting its use as a substitute for brick, and by stipulating that it shall be used in a proper manner, the building laws of this country would be far more likely to achieve their real end than is the case at the present time.

Another important reason for revision of the London Building Act, and the building regulations in large cities and towns generally, so as to give full play to the architect as a constructional engineer, is that steel frame or skeleton buildings can be erected far more rapidly than ordinary brick buildings.

Some people are very fond of telling us that for rapid construction we must go to the United States. We give full credit to our Transatlantic cousins for the well-organised methods that enable them to execute building and engineering works within periods of time that sometimes appear to be startling. It is the fact, however, as shown by frequent passages in the technical press, that British engineering firms are capable of equally expeditious work when permitted a free hand, and building contractors would be quite capable of providing similarly satisfactory records if skeleton construction on a rational basis were not practically barred by statute.

Under revised building regulations, making intelligent recognition of the valuable properties possessed by iron, steel, and concrete-steel as structural materials, we may confidently expect that British architects and contractors will not fall short of the standard set by their American *confrères* in respect of scientific and expeditious construction. The rapid execution of building works is really a matter of much moment to the owner, for it reduces the period during which capital lies idle. It is of equal importance in minimising discomfort and loss to the occupants of property in the immediate vicinity of the buildings under construction, and to the public at large by reducing interference with vehicular and pedestrian traffic. It is even of importance to the municipal purse in loss of rates.

The erection of a building in the customary manner is necessarily a somewhat slow process, commenced at the foundations and gradually proceeding, course by course, to the topmost layer of brick. Then, after a due interval, the work of plasterers, carpenters, and decorators follows in more or less leisurely succession. On the other hand, the design of a framed building permits the preparation in advance of a complete skeleton that can be erected very quickly on the site, and this being done, the enclosing walls can be commenced simultaneously on every story.

A most essential detail, however, in connection with skeleton buildings, is that the steel should be adequately protected from the effects of fire, but this is not a difficult matter, thanks to the admirable fire-resisting properties of Portland cement concrete. The recommendation of the British Fire Prevention Committee, that all steelwork should be protected by a 2-in. covering of concrete is one well worthy of universal adoption. In the United States terra-cotta tiles are largely employed for the same purpose. In the opinion of the writer, whether terra-cotta tiles be used or not, a coating of concrete applied directly to the steel should never be omitted, for, in addition to protecting the steel from fire, it is also necessary for preventing the percolation of moisture and consequent corrosion of the metal, thereby giving an assurance of prolonged life that would otherwise be difficult to guarantee. Thus, whilst advocating the modernisation of the Building Acts to the advantage of steel construction, the necessary safeguards against fire and corrosion must of course not be overlooked, and these, to the writer's mind, mean a suitable encasement of Portland cement concrete, which can be faced with terra-cotta or a decorative covering, as each individual case may demand.

Apart from the obstacles presented by existing building laws in the way of improved design and construction, certain enactments are undesirable because of their inconsistency. Stipulations as to the thickness of walls sometimes defeat their own object. For instance, it is particularly absurd to forbid any reduction of wall thickness in cases where steel stanchions would amply justify such reduction, and at the same time to permit the whole façade of a building to be carried by a steel girder without any more satisfactory intermediate support than that afforded by the window frames of a shop front, or to permit the whole corner of a building to be supported by two steel columns on either side of a doorway. Why the resistance of columns and girders acting without the assistance of brickwork should be taken into account by building laws that refuse to acknowledge the strength of similar members embedded in brickwork is one of those things that cannot be explained by any rational theory.

Again, if the steel possessed no strength when built into walls, as the London Building Act pretends, the insertion of a complete steel skeleton would constitute a source of weakness by displacing some of the brickwork, and by partially breaking up the continuity of that remaining. Of course, everybody knows that the contrary is the fact. But the steelwork being rigid, and not liable to settlement like masonry, actually tends to divide the outer brick construction into a system of curtain walls, each imposing unnecessarily heavy loads upon the steel members. So the provision of the law overshoots its mark and would diminish rather than increase safety if the structural engineer did not proportion the strength of his skeleton to carry the additional loads involved.

It would be easy to adduce further arguments against the illogical character of the London Building Act and kindred laws, but enough has been said to bring home the necessity for regulations of more intelligent nature, based, like the building codes of Continental and American cities, upon a just appreciation of modern materials and methods of construction.

HEILMANN & LITTMANN, *Archts*

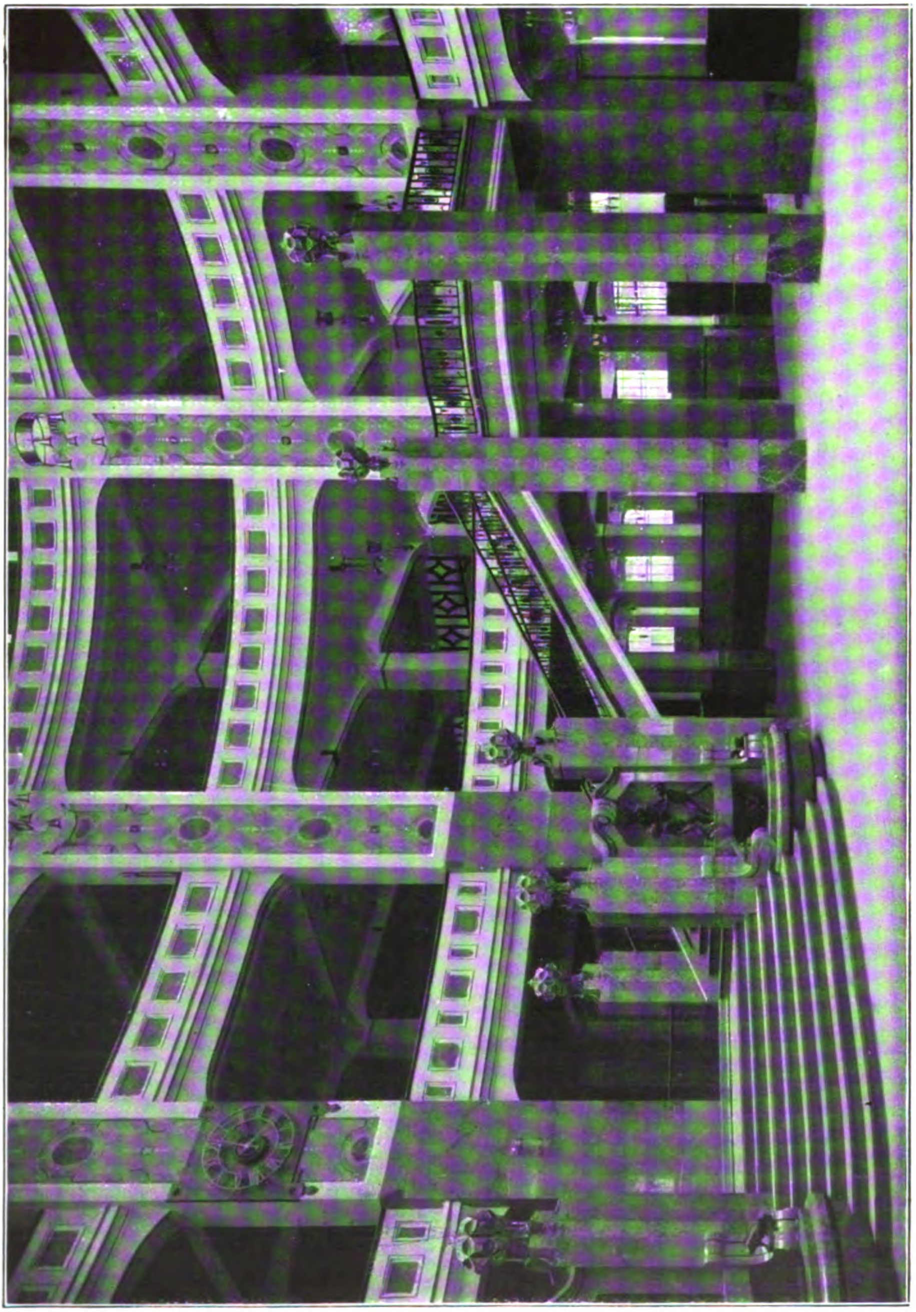


FIG. 2. NEW STORES AT MUNICH.
View of Reinforced Concrete Central Hall.

REINFORCED CONCRETE AT MUNICH.

THE "TIETZ" STORES.

Messrs. **HEILMANN** and **LITTMANN**, Architects.

We propose presenting, from time to time, particulars of important buildings in which reinforced concrete has been applied. The example illustrated, which occupies a site measuring some 180 feet by 180 feet, and has considerable architectural pretentions, was completed in under twelve months. Some important working drawings are reproduced.—ED.

The progress made in the application of reinforced concrete to business premises throughout Germany is something quite extraordinary; in fact, the majority of architects and engineers engaged in industrial work, as distinct from domestic work or public buildings, may be deemed to now generally favour its use for reasons of economy and adaptability.

Reinforced concrete has, in Germany, for some years practically been dealt with as a method of construction open to all, and not subject to proprietary rights or patents in the general sense, although, of course, there are specialist systems and specialist appliances put into operation in its application, which give individual firms of contractors or specialists well-merited claims for particular attention.

Secrecy on matters of calculation or formulæ is quite taboo, as is only to be expected in a country where detailed statical calculations have to accompany all drawings laid before the Building Act authorities for approval. In fact, what with the extensive literature on the subject, the various principles of design and calculation may be deemed now-a-days to be the common property of the German technical professions and building trade alike.

Reinforced concrete is not only being used for entire buildings, but also to a very great extent for the floors and supports in buildings of which the containing walls are of brick or stone. This appears to be particularly a feature of recent work in Bavaria, where the containing walls, with their architectural features, are frequently in brick or stone, whilst the entire internal work is in reinforced concrete.

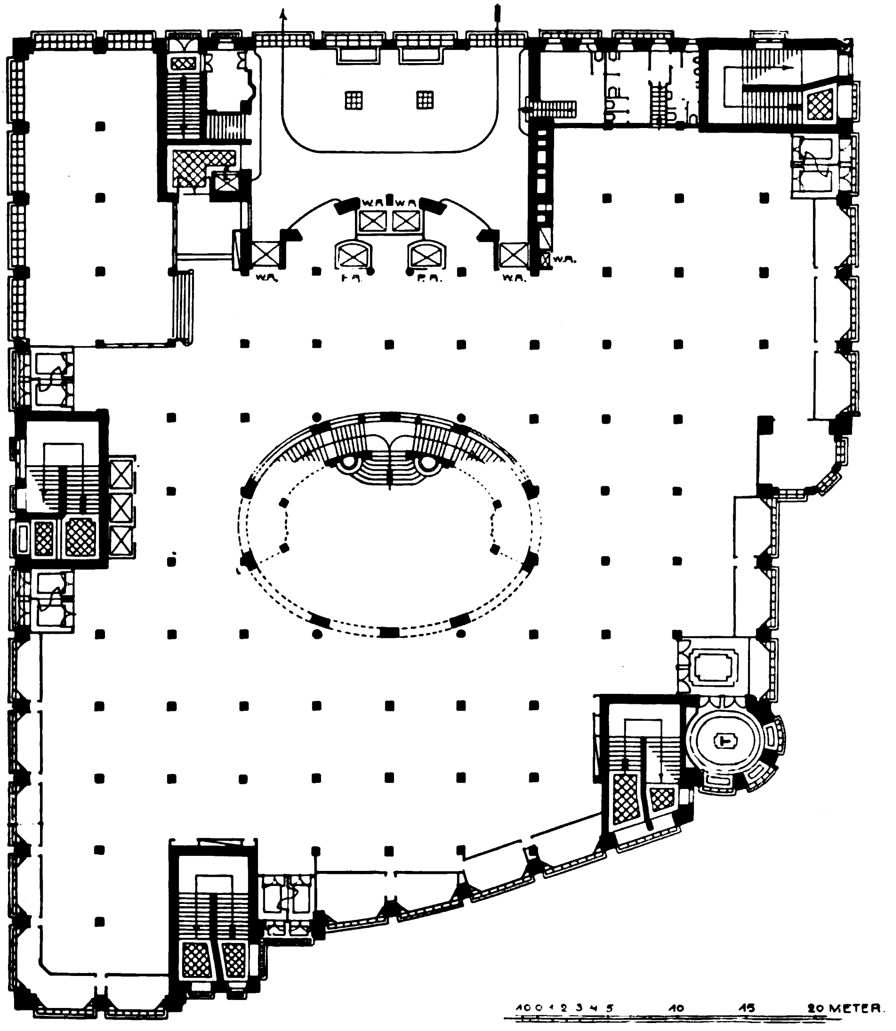


FIG. 3. NEW STORES AT MUNICH (GROUND FLOOR PLAN).

We are presenting an example of this description in the new "Tietz" Stores, a building of considerable architectural pretensions, occupying a very important site in Munich, and having a frontage of about 180 ft. to a depth averaging about the same dimension.

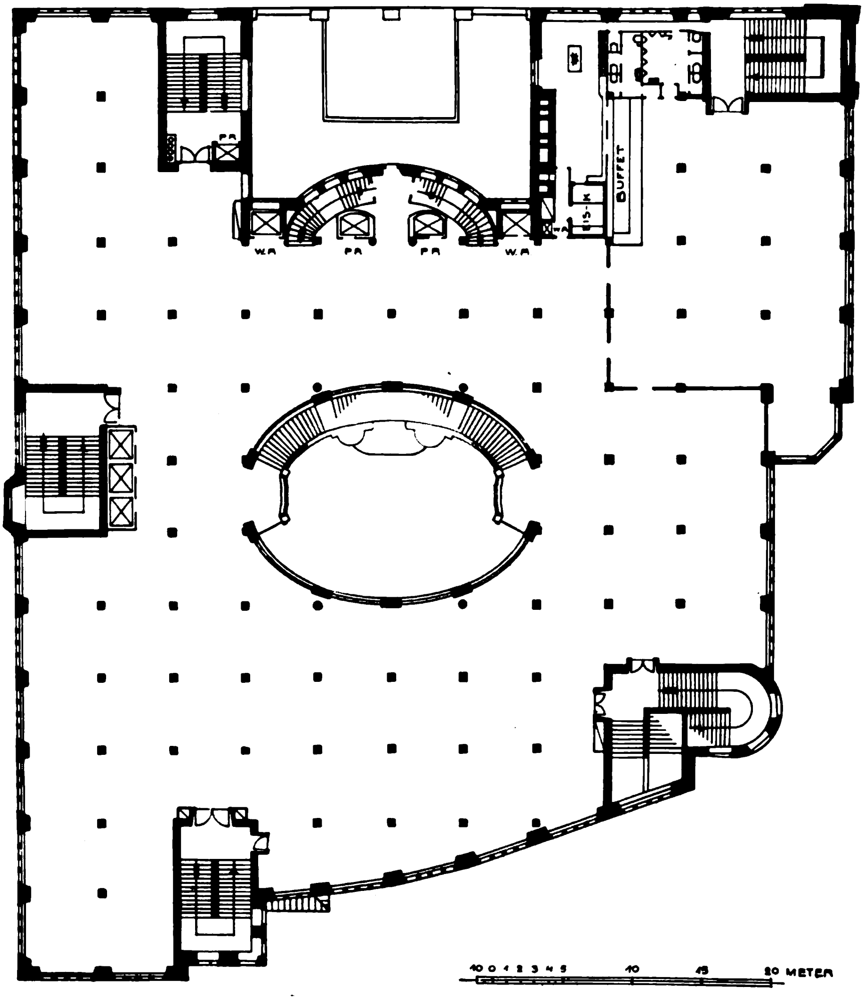


Fig. 4. New Stores at Munich (First Floor Plan).

This building has been designed and carried out by Messrs. Heilmann and Littmann, who acted both as architects and contractors, the last-named member of the firm being Professor Littmann, the well-known authority on architectural questions. The execution of the reinforced concrete work was sub-let to the Eisenbeton Company, in which, by the by, the firm named is interested.

From the plans and general section presented (*see* Figs. 3 to 5), the extent of the reinforced concrete work is easily ascertainable, comprising, as it does, the whole of the vertical supports and the entire floors.

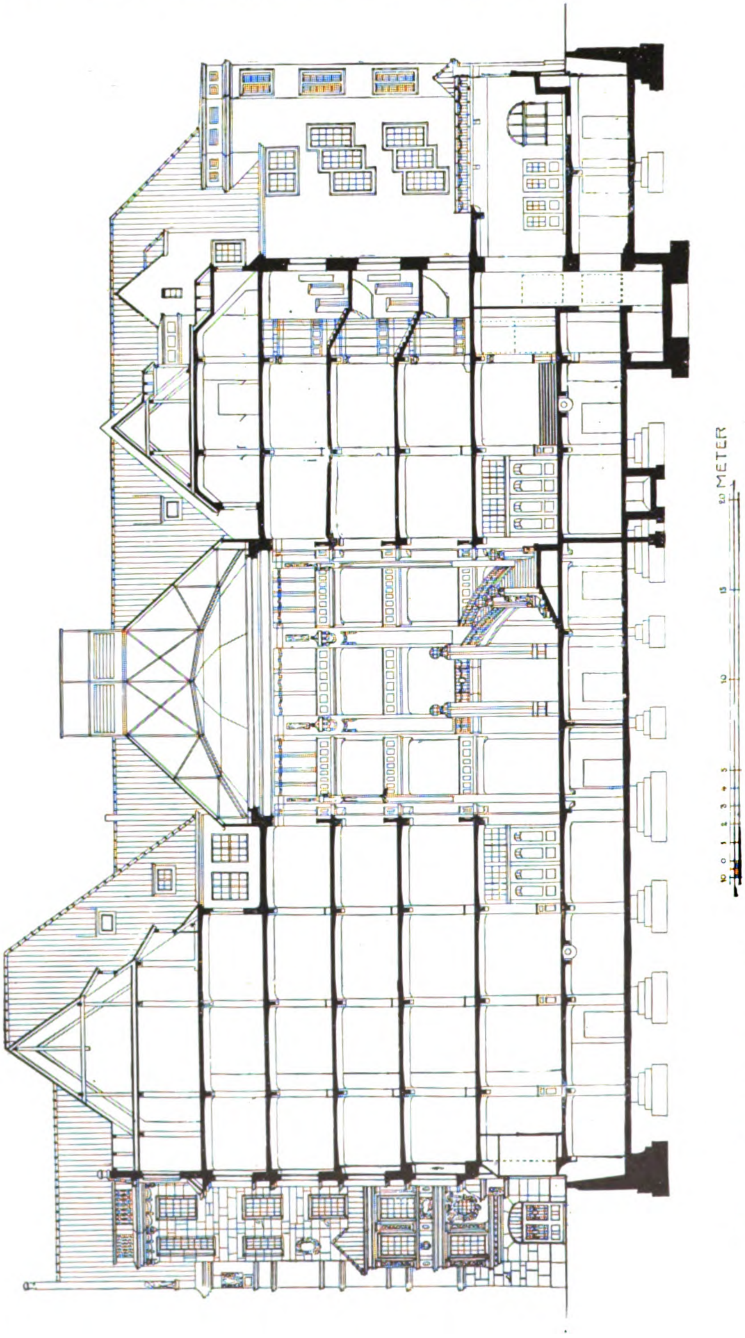


FIG. 5. NEW STORES AT MUNICH. LONGITUDINAL SECTION SHOWING REINFORCED CONCRETE CONSTRUCTION.

One of the remarkable features of this building is that, regardless of its dimensions, its excellent architectural rendering, and the great care which has been accorded to the smallest detail of its fittings and appliances, the time occupied from taking over the property, with a number of buildings standing, until the opening was only 12 months and 3 days, inasmuch as the gutting of the existing premises commenced on February 22nd, 1904, the excavations were commenced on March 3rd, 1904, and the building was completed on February 25th, 1905.

This achievement, remarkable in itself, is of particular interest, having regard to the considerable amount of reinforced concrete in the building, and should go far to show that the application of reinforced concrete by no means carries with it any delay in the execution of the work. We must further recollect that the winter months are extremely cold in Germany, and thus the time record of this building certainly does high credit to all concerned, and rivals the best practice of any country, including the United States.

We understand that several London architects and surveyors visited the building in course of erection on August 25th, 1904, at a time when the roof was being put on, and we hear that the whole of the reinforced concrete work was already then completed. The roof was, as a matter of fact, finished on September 3rd, and the windows provided with casements and glazed in by the end of that month.

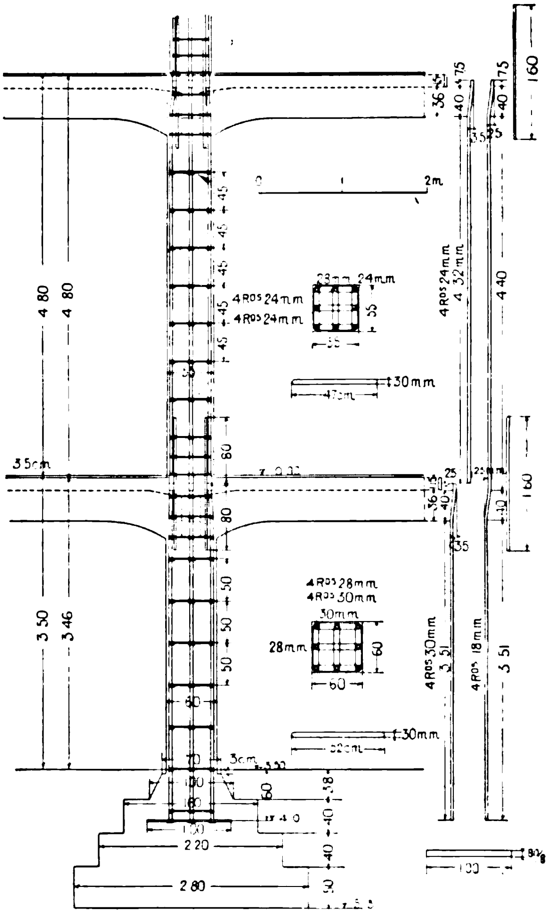


Fig. 6. Details of Reinforced Concrete Supports

The system of reinforced concrete utilised in this building can be easily ascertained from the detailed drawings (Figs. 6 to 8), on which the diameter of the rods, etc., is given on the metric system. The photograph (Fig. 10) further shows a floor in course of construction.

The concrete used throughout was of one part South German Portland

HEILMANN & LITTMANN, *Archts.*

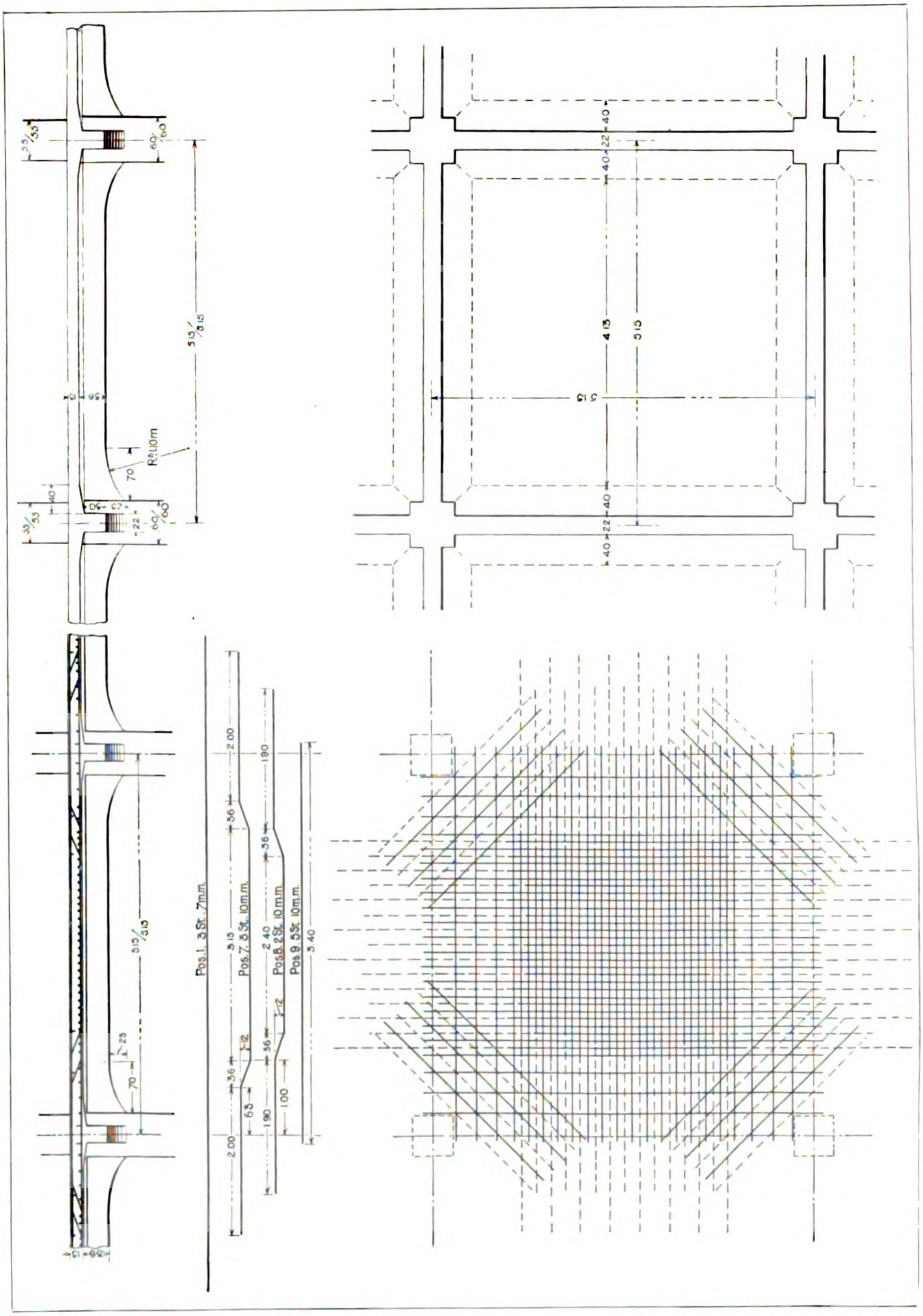


Fig. 7. New Stores at Munich. Details of Reinforced Concrete Floors.

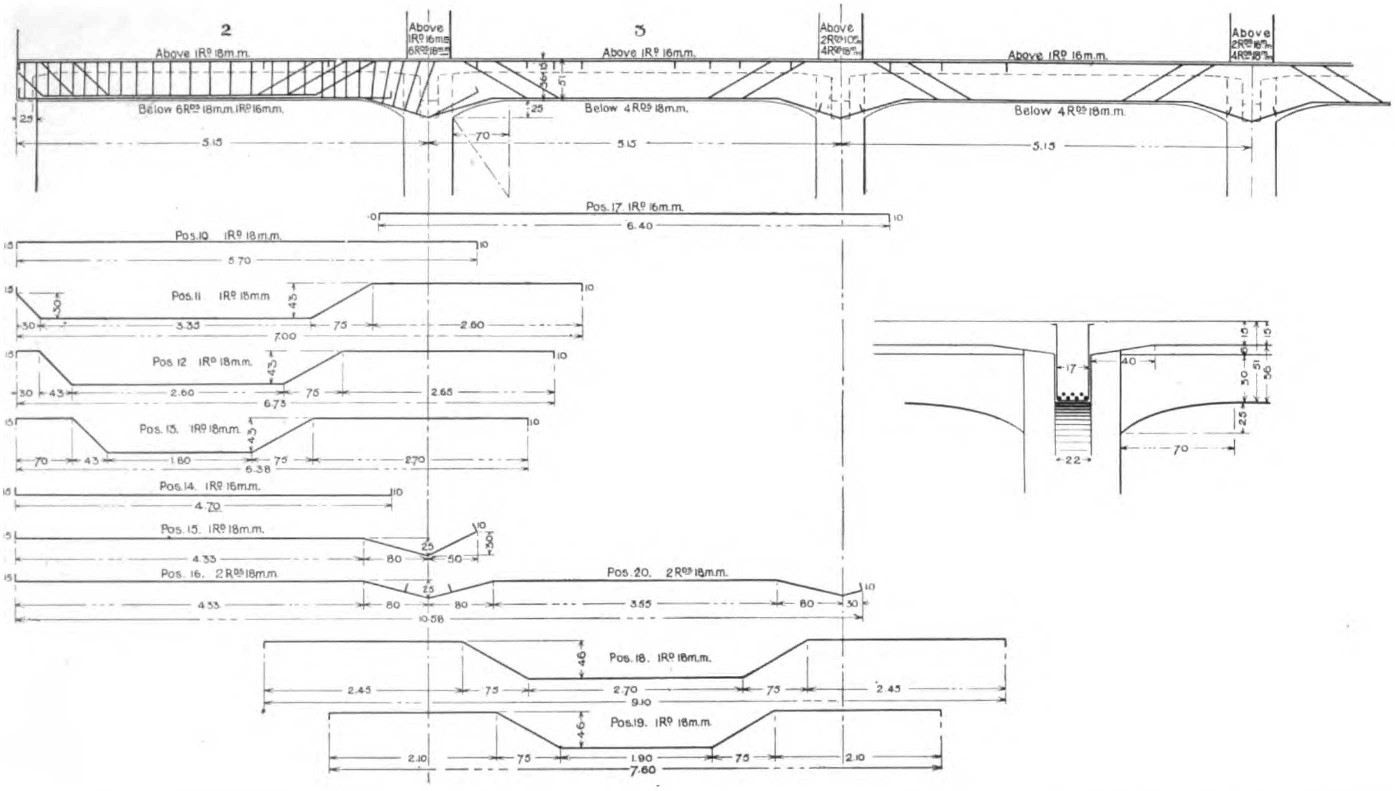


FIG. 8. NEW STORES AT MUNICH. DETAILS OF REINFORCED CONCRETE FLOORS.

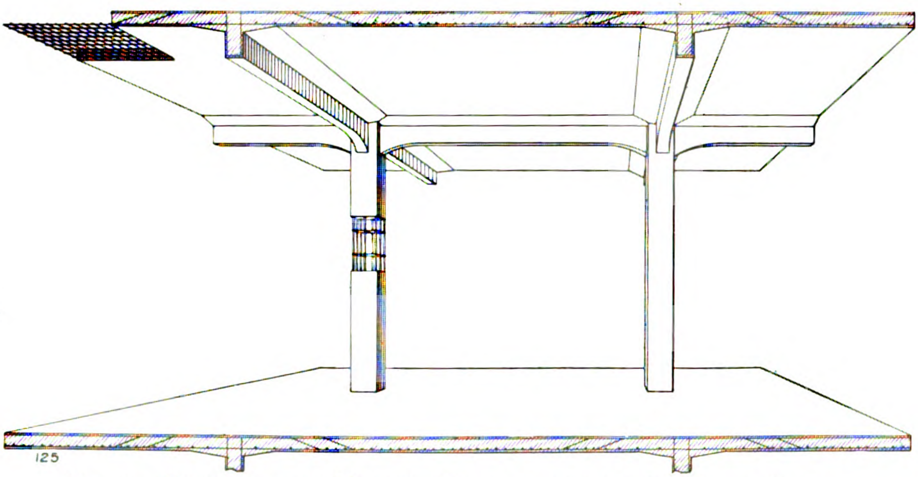


FIG. 9. NEW STORES AT MUNICH. DIAGRAM SHOWING SYSTEM OF FLOORS AND SUPPORTS.

cement to four parts of crushed gravel, passed through a sieve with a mesh of 12 mm., *i.e.*, ½ in. The mixing of the concrete was with the aid of mechanical mixers.

The concrete was applied in a very wet condition, *i.e.*, in a far more fluid condition than is generally the case with us, the idea being that this results in greater adhesion—an idea amply proved by experiment. A crushing test at Munich, with material applied very wet, as compared with its ordinary application, showed a considerable advantage after the 100 days' drying.

As to the rods used, they were circular in section throughout, *i.e.*, no angular rods were used.

We understand the London architects and surveyors who visited the building were much impressed by the excellence of the workmanship and the rapidity with which the building was being carried up.

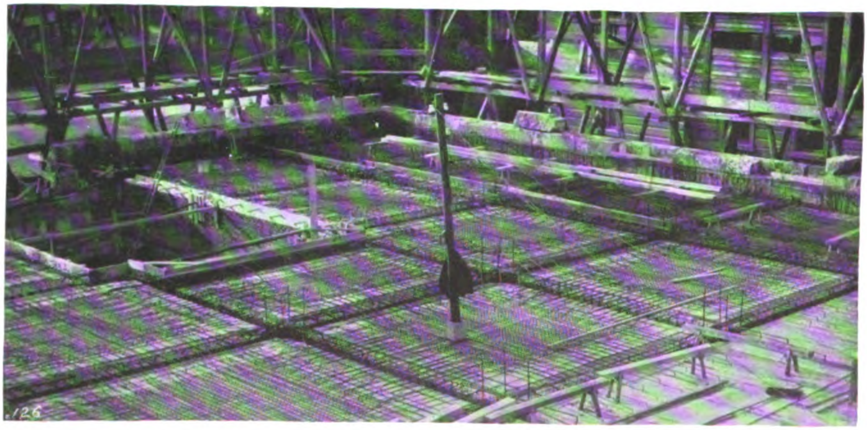


FIG. 10. NEW STORES AT MUNICH. FLOORS IN COURSE OF CONSTRUCTION.

Reinforced Concrete for Foundations of Buildings.

By CHARLES F. MARSH,
M.Inst C.E., M.Inst.M.E.,
Author of "Reinforced Concrete."

The advantages of employing reinforced concrete for difficult foundations claim the attention of engineers and architects alike. The following article summarises the subject in a few words, with examples. - ED.

AMONG the many purposes for which reinforced concrete may be advantageously employed, the construction of footings and foundations is by no means the least important. Where the ground upon which a building must be erected is of a yielding nature, either by reason of having been originally made up to a level above the true ground surface, or the nature of the subsoil, it becomes necessary to spread the footings of walls and columns and so reduce the intensity of pressure.

Reinforced concrete is particularly adapted to a use of this kind, since, whereas an ordinary foundation must be of considerable depth to withstand the cantilever action to which the footings are subjected, the placing of reinforcements near the lower surface enables the thickness of ordinary footings to be considerably reduced.

It is also possible, by the employment of reinforced concrete, to form a raft covering the whole area upon which a building is to stand, and so distribute the loads over the entire site. In cases where the ground upon which the foundation must rest is of a very soft and yielding nature, the above method may enable a building to be erected which would be impossible under ordinary conditions.

The reinforced concrete pile may frequently be used with advantage to support the foundations of a building, the heads of the piles being formed as one with the foundation slab for the columns or walls.

For buildings subjected to the vibrations of machinery, where the foundations require special attention, reinforced concrete will always show to advantage; while for engine-bed foundations, particularly when the engine is quick running, it is an eminently suitable material to employ.

Reinforced concrete or brickwork may also be used in the form of inverted boxes formed of intersecting walls with a continuous covering slab, the reinforcements for the walls being carried into the slab and *vice versa*. The interior of the box-shaped compartments is filled in with well-punned material to the level of the top of the walls, and the slab is then formed on the surface of the filling.

This form of foundation is especially suitable in cases where vibrations have to be resisted, since any slight settlement of the cells further compresses the filling and increases the resistance offered by the foundation. For machinery foundations the boxed form of construction is an excellent method to employ, since the cost will compare very favourably with the usual heavy blocks of concrete, the resistance to vibration is very great, and it is easy to form passageways for access and hand holes for the heads of the holding-down bolts.

Economy.

The cost of reinforced concrete construction is always considerably enhanced by reason of the heavy and frequently intricate nature of the falsework required; but this factor of the cost is almost entirely eliminated in the case of foundations, since the concrete is placed upon or against the excavation and requires in most cases no timber falsework, while in others only a small percentage is employed compared with that requisite for work above ground, where the walls, columns or floors have to be rigidly supported until they become sufficiently hardened.

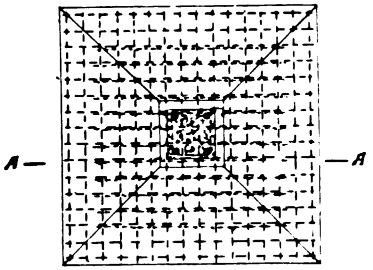
Column Foundations.

The form usually adopted for reinforced concrete column foundations is shown in the sketch Fig. 1, and a similar method is employed for the footings for walls. The vertical rods of the column bear against a metal plate or series of plates so as to distribute their pressure.

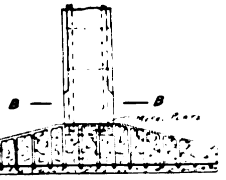
The reinforcing rods of the foundation block are placed near the bottom, as it is here that tensile stresses will occur.

It is probable that in a slab foundation such as that shown, the shearing stresses will be sufficiently resisted by the concrete, but a re-inforcement, similar to the wires shown passing round the bars and through the upper portion of the concrete, is frequently used and serves to tie the several parts together. The block is bevelled off from the centre towards the sides, since the bending moment is theoretically *nil* at the outside and maximum under the faces of the column.

In the case of the footing for a wall the reinforcements would only require to run transversely, but it is well to place a few in a longitudinal direction to distribute the loading on the main transverse bars. Instead of rods or bars, a reinforcement of expanded metal or any form of wire mesh could be employed equally well.



PLAN ON B-B



SECTION ON A-A

FIG. 1. COLUMN FOUNDATIONS.

Pile Foundations.

The method usually adopted when piles are used to support a foundation is shown in the sketch, Fig. 2.

A group of piles is first driven, after which the concrete at their heads is knocked away, leaving the rods projecting above the surface of the bottom of the foundation; the footing block is then formed, the heads of the piles being thus made monolithic with the foundation slab.

When a framed superstructure is to be erected formed of columns and lintels, with wall slabs filling up the bays, pile foundations are placed under the columns, and the footings for the walls are made continuous with the foundation blocks for the columns. In this case, since the wall footings span the distance between the column foundation blocks, they must be designed as beams; such a form of construction is shown in Fig. 2.

The piles may be moulded of any form; rectangular, triangular, octagonal, circular, and other forms being employed.

The usual method of reinforcement consists of longitudinal bars of round, square, L or other section, held together at fairly close intervals by a wrapping of wire or by perforated flat strips.

An ordinary pile shoe is generally used, the straps being bent in at the top to obtain a hold on the concrete, and the reinforcing bars of the pile being bent in so as to bear against the solid metal at the point.

Sometimes piles are reinforced with rolled joists framed together or by themselves, the point being formed in some cases by cutting away the web for a short distance and bending in the flanges.

M. Considère's method of hooping concrete under compression with spiral windings of wire is now also employed for the construction of piles

When designing piles it should be borne in mind that they must be able to resist the bending moments due to transport as well as the direct pressure and the shocks while the driving is in progress.

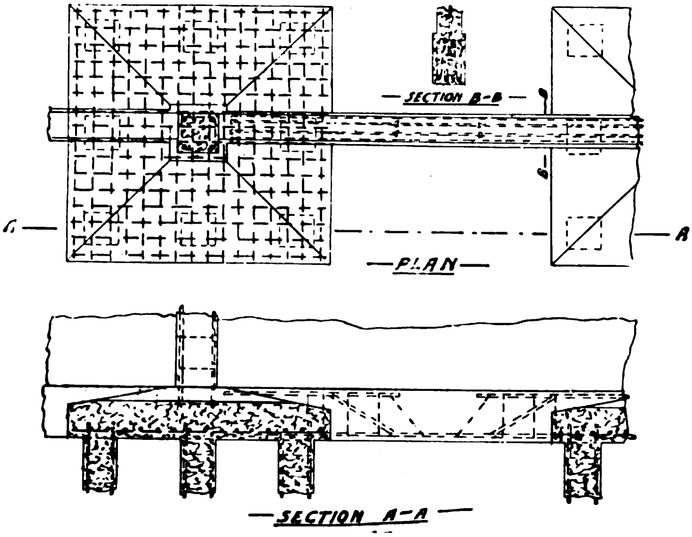


Fig. 2. Pile Foundations.

They are usually driven with an ordinary pile driver and monkey, the head being partially protected by a metal cap filled with bags of sawdust or other similar material to form a cushion, or the same object is attained by the use of a timber dolly. The water jet is also employed in suitable cases, the jet pipe being frequently cast in the concrete of the pile.

When reinforced piles were first introduced they were always moulded vertically in order that the layers of concrete might be in planes at right angles to the direction of the pressure, but latterly they have been moulded on their sides, whereby greater economy of falsework is obtained, and no evil consequences have resulted.

With a material such as concrete, if the deposition of the successive layers is not unduly delayed, it does not appear that the strength will be effected to any extent by reason of the direction of the ramming. There should, however, be no stoppage in the moulding of a pile in a horizontal position, such as leaving off for the night, and there is no reason why such a break should occur, since more men can be employed on the construction of a pile when the moulding is horizontal than when it is vertical.

Piles reinforced by a spiral winding must of necessity be moulded vertically, since the continuous winding would not be properly surrounded with concrete if they were moulded horizontally.

Raft Foundations.

When the whole area on which a building is erected is covered with a raft of reinforced concrete, the construction usually takes the form of a series of inverted beams and slabs, the reinforcement being placed near the upper surface at the centre of the spans and some bent down to approach the lower surface near the place of application of the loads; further bars being added here if found necessary. Such a form of construction is shown in the sketch, Fig. 3.

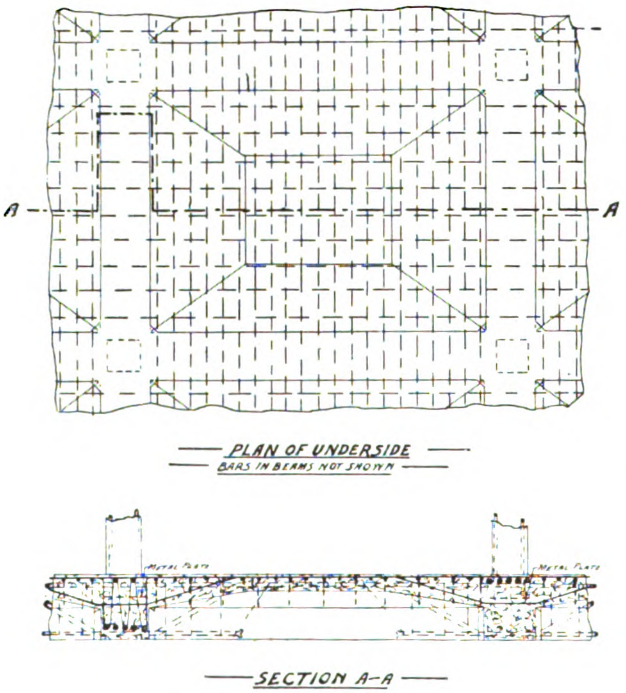


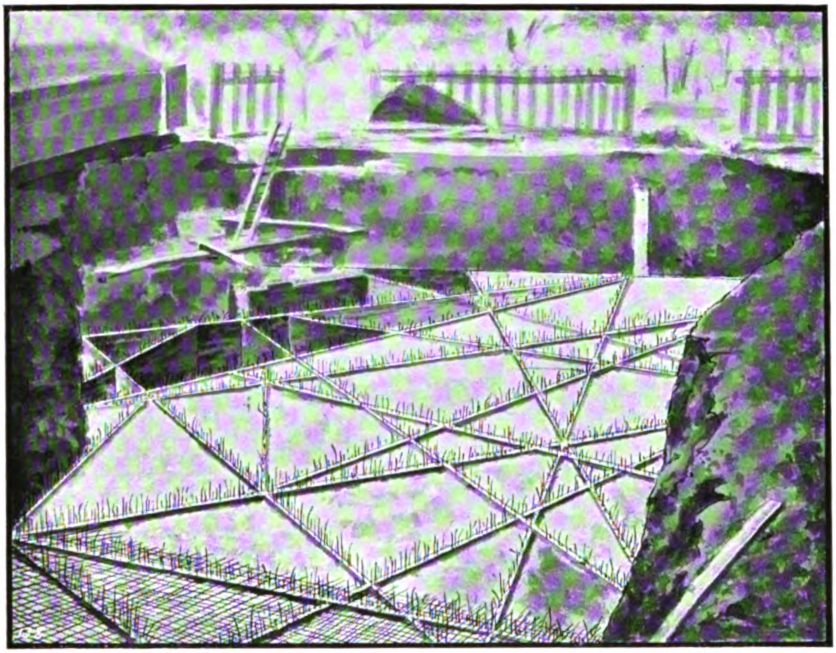
Fig. 3. Raft Foundations.

Box Foundations.

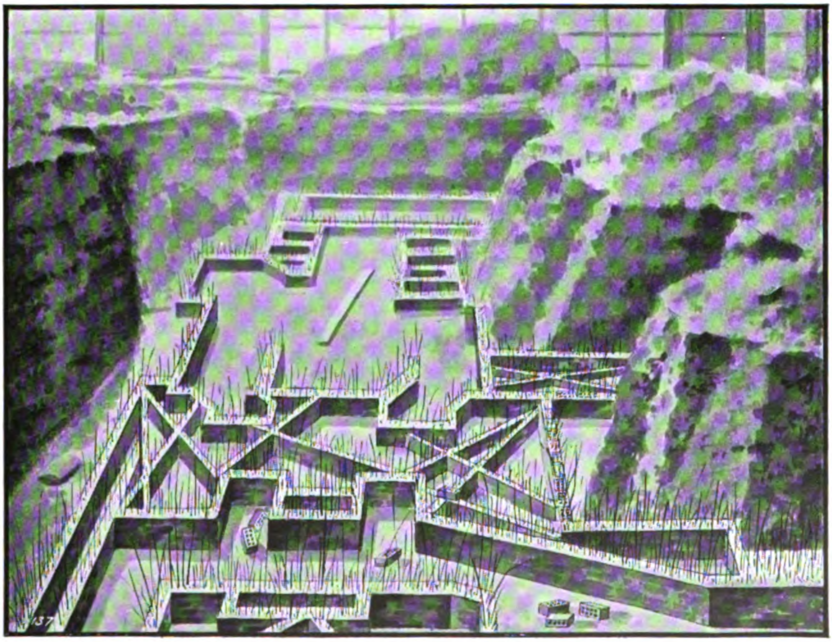
Types of inverted box foundations are shown in the sketches, Figs. 4 and 5. They are both of the Cottançin wire-threaded brick wall and concrete slab construction, but a similar form of foundation could be employed with concrete walls and any wire mesh, expanded metal or rod reinforcement.

Fig. 4 is the foundation of a building, and shows part of the cells filled in ready for the concrete slab. Fig. 5 is the foundation for a high speed engine, and shows how well this form of construction can be adapted to the requirements for holding-down bolts, etc.

When there is a passage way, the walls of the boxes at the sides of the space must be reinforced strongly so that they may resist the outward pressure of the filling compressed by the weight of the superstructure upon it.

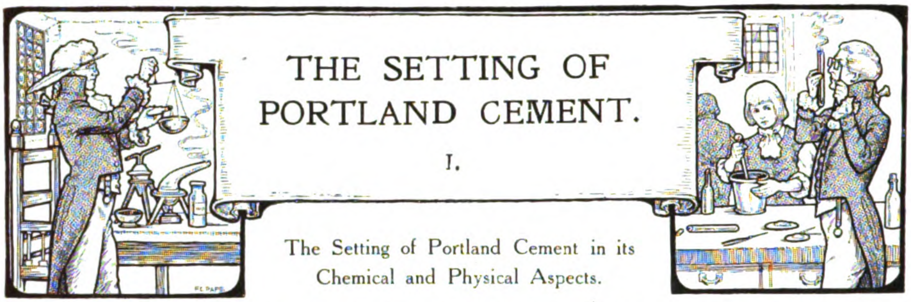


Building Foundation.



Engine Bed Foundation.

FIGS. 4 AND 5. REINFORCED CONCRETE BOX FOUNDATIONS.



THE SETTING OF PORTLAND CEMENT.

I.

The Setting of Portland Cement in its Chemical and Physical Aspects.

By CECIL H. DESCH, D.Sc., Ph.D.

To all engaged in constructional engineering, and more particularly in the application of concrete and reinforced concrete, the question of the setting of Portland cement is one of the utmost importance. Having regard to this, arrangements have been made by which a series of articles will be presented by well-known authorities at home and abroad, dealing with the question in its chemical and physical aspects, and these various articles will finally be summarised with the view of presenting the more important facts and the consensus of opinion.—ED.

PART A.

THE various substances of the class of cements, differing widely as they do in their chemical nature, are alike in being able to assume a plastic condition, in which they can be moulded and applied to surfaces which it is desired to unite, and subsequently to harden, to a compact mass possessing considerable mechanical strength. The chemical and physical processes involved in these changes may vary very greatly in cements of different kinds. We are here concerned only with those cements of which the plasticity is brought about by mixing with water, the mass subsequently hardening spontaneously or on exposure to the atmosphere, and, of this limited class, only its most important member, the commercial product known as Portland cement, will be considered in any detail.

The changes taking place in the passage from the plastic to the hard state are of two kinds. There is first a definite chemical reaction or series of reactions occurring between the cement and the water, in most cases also between the different original constituents of the cement, and finally between the primary product and the substances contained in the surrounding air or water. But even a complete study of these reactions would not tell us why the plastic mass becomes firm, or why the solid product increases in hardness with time. To understand this we have to examine the physical processes occurring during the stages of mixing, setting, and hardening, processes involving solution, crystallisation, etc., and demanding physical rather than analytical methods for their investigation. The problem has therefore two aspects, a chemical and a physical one, the first of which only will be considered at present.

The simplest cement, from a chemical point of view, is plaster of Paris. In its burnt state this is the hemihydrate of calcium sulphate, which in contact with water is converted into the dihydrate, the latter being at the ordinary temperature the stable form. The reaction is therefore one of simple hydration according to the equation:

$$CaSO_4, \tfrac{1}{2}H_2O + 1\tfrac{1}{2} H_2O = CaSO_4, 2H_2O.$$

Why this dihydrate should form a solid mass, possessing considerable coherence, is a physical question, and will be discussed later.

In the case of lime mortars the first reaction, the slaking of the lime, is also one of hydration, the quicklime combining with water to form the stable hydroxide, much heat being developed at the same time:

$$CaO + H_2O = Ca(OH)_2.$$

The product in this case is, however, not a resistant solid, but a friable mass without coherence. If mixed with water and some inert material, such as sand, the first process is simply one of desiccation, but the mass produced has little mechanical strength, and may again be reduced to the plastic state by mixing with water. However, on long continued exposure to moist air, which always contains carbon dioxide, a further reaction takes place, and the lime is converted into the hard crystalline calcium carbonate:

$$Ca(OH)_2 + CO_2 + = CaCO_3 + H_2O,$$

although this change does not proceed completely through the mass, even after many years' exposure to the atmosphere. In puzzuolanic mortars, the lime, after slaking slowly, combines with the silicious constituents of the added matter to form calcium silicate.

Portland cement is made by heating an intimate mixture of chalk or limestone, which is essentially calcium carbonate, with clay, which may be regarded as a compound of lime silica, and alumina. the other constituents being of secondary importance. The calcium carbonate is decomposed on heating to about 800° C., and the lime thus produced enters into reaction with the other substances present at the temperature of incipient fusion of the mass. The completeness of the reaction is dependent on the temperature attained, on the fineness of the original mixture, and on several other factors. As might be expected from its composition, the chemical reactions occurring both in the preparation and in the setting and hardening of Portland cement are exceedingly complex, and chemists have not yet succeeded in solving the problems presented. However, it may be said that at least the main outlines are now clear, although several important points are still subjects of controversy.

A chemical analysis of a Portland cement clinker merely shows it to contain lime, silica, and alumina, together with small quantities of the oxides of iron and magnesium. Constituents of subordinate importance are, as before, neglected. The ultimate analysis does not tell us more than this, and a proximate analysis of cement, showing how these oxides are combined with one another to form definite compounds, is in the present state of our knowledge only possible in a very imited degree, and even then only in an indirect way. Analytical methods of this kind, devised with the object of determining the constitution of cement, such, for instance, as the method for the estimation of free lime by extraction with sugar solutions, etc., are all open to the objection that the reagent itself brings about important changes in the cement with which it is in contact, so that in the case mentioned the lime thus extracted is not demonstrated to have been present in the original cement, since it may equally well have been produced by the hydrolytic action of water on a calcium silicate or aluminate.

The converse method, that of synthesis, offers a better prospect of success. This consists in preparing those compounds, whose presence in cement is suspected, from pure materials, and comparing their properties with those of the commercial product. This method has already yielded valuable results, but is yet not without uncertainty, arising chiefly from the difficulty of determining whether we are dealing with a definite compound or not. The homogeneity of a product obtained by fusing together, for example, lime and silica or alumina, is no proof of its chemical individuality, since this class of substances forms solid solutions of widely varying composition, a fact too often overlooked in investigations into the constitution of cement. Chemical formulæ, often quite incompatible with the principles of atomic valency, have been assigned to such products merely on the strength of their homogeneous appearance, and much confusion has thereby been introduced into the problem. The best method of determining the existence of chemical individuals, which has already yielded the most brilliant results in the case of metallic alloys, is that of studying the melting points and thermal transformations of mixtures of progressively varying composition. So far, only meagre results have been obtained in the case of the silicates and aluminates, owing mainly to the difficulty of determining the temperature at which fusion takes place. Substances of this kind are frequently so viscous at temperatures slightly above their melting point as to possess an apparent rigidity almost equal to that of the solid, and a merely gradual softening therefore appears to take place. The recent important researches of Day and Allen[*] on the felspars have, however, determined the conditions under which the melting points of silicates may be sharply measured, and a careful application of their methods may be expected to do more than anything else to solve this vexed question.

It may be considered as established that the principal active constituent of Portland cement is a calcium silicate. By fusing an intimate mixture of finely divided chalk and silica in the proportion necessary to yield a product of the composition 3 CaO, SiO_2, Newberry[†] has obtained a silicate which, when finely ground, sets with water, and hardens completely without cracking, yielding briquettes approaching in strength the best commercial cement. This substance is therefore regarded by Newberry, Le Chatelier and others as a true tricalcium silicate. Rohland, on the other hand, regards it as a solid solution of lime in a less basic calcium silicate. If this view be accepted, the formula written above nevertheless expresses the upper limit of the solubility of lime in calcium silicate, since any further addition of lime gives rise to a cement which expands and cracks in setting, proving unmistakably the presence of a portion of the lime in an uncombined or undissolved state. In the absence of an accurate thermal study of the kind suggested above, it is hardly possible to decide between these two representations of the facts, and from a practical point of view their difference is of minor importance. In either case, the active lime, whether combined or merely dissolved, is in an entirely different state from so-called "free lime," which expands during hydration. Considering these facts, the attempt of Mayer and others to assign definite structural formulæ to the calcium silicates must be regarded as at least premature. For our present purpose it is sufficient to write the formula of the active constituent of Portland cement as $3\ CaO,\ SiO_2$, without making any further assumption as to the state of combination of the constituent oxides.

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[*] *Amer. Journ. Sci.* 1905 [iv.], **19**, **93**; also Publ. **31** of the Carnegie Institute of Washington.

[†] See references at the end of this article.

This synthetic cement was prepared by fusion, which necessitates the high temperature of the electric furnace or of the oxy-hydrogen flame. If the temperature of fusion is not reached, combination is incomplete, and the product contains free lime. In the actual manufacturing process, however, the attainment of such high temperatures is impracticable, even in the rotary kiln. It is therefore necessary to lower the fusing point of the mixture. This is done by the addition of alumina derived from the clay, forming a calcium aluminate or silico-aluminate. Owing to the greater fusibility of these substances, the mass sinters at a temperature which is attainable in ordinary working, and the necessary reactions are enabled to proceed. Newberry has shown that the composition of a Portland cement clinker may be represented by the formula:—

$$x\ (3\ CaO,\ SiO_2) + y\ (2\ CaO,\ Al_2O_3).$$

(Magnesia and iron are, for the moment, neglected). In practice, however, the combination is always incomplete, and in order to avoid the presence of free lime it is necessary to keep the proportion of lime somewhat below that indicated by the formula. The degree of completeness of the reaction depends on the temperature, and the higher the temperature of the manufacturing process, the nearer the lime in the mixture may approach the theoretical limit. A rotary kiln cement may therefore contain a higher proportion of lime than one manufactured in an ordinary kiln without giving an unsound product. Fineness of grinding of the raw materials also favours completeness of reaction.

The silicate and aluminate do not exist in the clinker as separate entities, but as solid solutions. By microscopic examination, Le Chatelier and Törnebohm have identified four such substances, known as alite, belite, celite and felite respectively. Until the optical and other properties of these constituents, as occurring in cement clinker from different sources, have been thoroughly examined and compared, it is impossible to determine their exact nature with any degree of certainty.

Oxide of iron plays a part similar to that of alumina, but the products are more easily fusible. Magnesia plays a part similar to that of lime, but tends to retard the chemical changes and to make the re-action therefore incomplete. The small quantities of alkaline and other salts do not take part directly in the formation of cement, but may exercise an important influence on the time of setting.

The clinker in its massive form is almost inactive, and must be brought into a state of fine division by grinding before it can be used. The further chemical changes which take place during the processes of storage and aeration must be passed over; they tend to rectify slight errors of composition due to incomplete reaction. We come now to the effect of water on Portland cement in its ground state. The process, as in the case of the other cements mentioned, is essentially one of hydration, and is usually separated into the two stages of "setting" and "hardening." A cement sets when it loses its plasticity and becomes more or less firm. It is then no longer capable of being applied to a surface or of adhering to it. In this state, however, its mechanical strength and cohesion are inconsiderable. Since the whole process takes place gradually, the "setting time" is, within certain limits, an arbitrary point, not corresponding with any clearly defined chemical or physical change. It is defined as the time required to reach a consistency at which a Vicat needle of given weight, or other similar instrument, just fails to indent the surface. On the other hand, the "hardening" process is one which proceeds very slowly, the hardness and mechanical strength of a good cement increasing after setting for months and even years.

It is now generally agreed that the setting is brought about by the hydration of the calcium aluminate and probably also ferrite. Calcium aluminate, $2\,CaO.Al_2O_3$ (writing the formula thus to avoid any assumption as to the nature of the compound present), sets with water almost as rapidly as plaster of Paris, but the product has little cohesion, and the hydrated aluminate contributes little to the ultimate strength of the cement. It, however, fulfils the purpose of holding the mass together in such a way as to allow the more important reactions of the silicates to proceed under favourable conditions.

Assuming the active constituent of the cement to be represented by the formula $3\,CaO,\ SiO_2$, the action of water on it consists in a process of hydrolysis and in one of simple hydration, represented approximately by the following equation:—

$$3\,CaO,\ SiO_2 + 4\tfrac{1}{2}\ H_2O = CaO,\ SiO_2,\ 2\tfrac{1}{2}\ H_2O + 2\ Ca\,(OH)_2,$$

the tricalcium silicate being decomposed into lime (the hydrated or "slaked" compound, calcium hydroxide) and a monocalcium silicate, which combines with a further quantity of water to form a crystalline hydrate. The quantities of water represented in the above equation are those suggested by Le Chatelier, but cannot be regarded as having been established with any great degree of certainty. However this may be, the hardened cement is to be considered as consisting of a mass of crystals of calcium hydroxide and of a hydrated calcium silicate. Why such a mass should possess great cohesion is a question to be dealt with in the second portion of this article. Obviously these lime crystals are capable of absorbing carbon dioxide from the air, and thus of undergoing a further hardening

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The following papers are among the most important of those dealing with the subject:—

H. Le Chatelier: "Recherches expérimentales sur la Constitution des Mortiers Hydrauliques." 1904. (The collected papers of this author on the subject).

S. B. Newberry and W. B. Newberry: *Journ. Soc. Chem. Ind.* 1897.

S. B. Newberry and M. M. Smith: *Bull Soc. d'Encouragement.* 1903. 640.

A Meyer. *Tonindustriezeitung.* 1902. 26, 1895.

Törnebohm: "Ueber die Petrographie des Portlandzements." 1897.

P. Rohland: "Der Portland-Zement vom physikalisch-chemischen Standpunkte." 1903.

A good account of the subject is also given by P. Rohland in Abegg's "Handbuch der Anorganischen Chemie," Vol. II Pt. 2, 1905.

process, as in the case of an ordinary lime mortar. Also, if the plan occasionally adopted on the Continent, of mixing volcanic trass with the cement, be employed, this lime will combine with the silicious constituents, as in a puzzuolanic mortar.

If we accept Rohland's view of the constitution of cement, the above description only requires slight modification. The action of the water is then considered to be, not a hydrolysis of a basic calcium silicate, but a simple hydration of the less basic silicate and of the lime held by it in solid solution. This lime not being "free," would not bring about the expansion which occurs in the hydration of free lime, and causes the cracking observed during the setting of badly-made cements, either under actual working conditions or in the course of the water test. The final result would be the same as that required by Le Chatelier's hypothesis, a mixture of crystalline calcium hydroxide and hydrated calcium silicate.

One further point requires to be mentioned. The velocity with which the above reactions take place varies with the physical conditions, such as fineness of grinding, temperature, quantity of water employed in mixing, etc., and also with the presence or absence of certain chemical substances which act as catalytic agents, accelerating or retarding the reactions of hydration. The best known of these is calcium sulphate, which exercises a retarding influence, and gypsum is therefore added to cements in order to retard the setting. Alkaline salts, present in the original raw materials, or derived from the ash of the fuel employed, may also exert an influence. The mechanism of this action will be discussed when treating of the physics of the setting and hardening processes.

(To be continued.)

THE PRESERVATION OF IRON AND STEEL.

By B. H. THWAITE, C.E.

The collapse of a part of the Charing Cross Terminus roof has again called attention to the absolute necessity of carefully preserving iron and steel from corrosion, a matter all too frequently neglected. In the following article the causes and chemical aspects of corrosion are dealt with, as also the question of protection afforded respectively by (a) cement, (b) paint, and (c) solutions. The article has been divided into two parts, the latter half appearing in the next issue.—ED.

MORE than a quarter of a century ago* the writer stated the opinion "that "one of the most dangerous forms of construction was that in which reliance for "structural strength depended upon unprotected metals."

In consequence of the partial collapse of the Charing Cross Station roof, considerable attention has been directed towards the condition of similar structures, and doubts are openly expressed as to the advisability of employing iron and steel so freely in the future as these metals have been employed in the past. It is always unwise to draw general conclusions from an isolated experience, and such a course is particularly to be depreciated in the case of the Charing Cross disaster, although this occurrence will doubtless furnish useful lessons when all attendant circumstances are fully known and analysed.

The object of the present article is to consider the effects of corrosion upon iron and steel, and to discuss methods by which the permanence of structures in which these materials are used may be extended by the application of preservative methods.

THE CHEMICAL ASPECT OF CORROSION.

When iron or steel is exposed to the influence of air containing water vapour and acids, the process of decay, generally described as oxidation or rusting, is commenced.

For the production of rust three substances are necessary—oxygen, aqueous vapour and an acid—and the intensity of the action depends upon the proportions of aqueous and acid vapours contained in the air. The rusting of iron takes place in two stages, and as carbon dioxide is the acid most generally present, the nature of the reactions may be thus expressed :—

$$(1)\ Fe + H_2O + CO_2 = FeCO_3 + H_2.$$

$$(2)\ 2FeCO_3 + 3H_2O + O = Fe_2H_6O_6 + 2CO_2.$$

In the first stage, water and carbon dioxide produce carbonate of iron concurrently with the liberation of hydrogen, and in the second stage the carbonate of iron combines with water and oxygen to form ferric hydrate, or rust, the carbon dioxide being set free.

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* See Article on "The Preservation of Iron and Steel for Oxidation and Corrosive Influences" in the *Universal Engineer*.

The above equations do not precisely express the chemical changes taking place, because iron rust is not pure ferric hydrate, and its composition is further complicated by the occurrence of mineral acids, such as the oxides of sulphur in the atmosphere. But the explanation is sufficient to give a general idea of the process.

Thermal effect may displace that of an acid—for instance when iron or steel are exposed to heated air, oxidation proceeds in two stages, which may be expressed as follows :—

$$(1)\ 2Fe + O_3 \text{ of air} = 2FeO + O.$$
$$(2)\ 2FeO + O = Fe_2O_3$$

When superheated steam is present, a third form of oxidation is produced, that is, magnetic oxide, or forge scale Fe_3O_4, thus :—

$$3Fe + 4H_2O \text{ (super-heated steam)} = Fe_3O_4 + 8H.$$

The effect of oxidation is not only destructive to the integrity of the metal, but it may also have a disruptive influence. For instance, an iron band or tie-rod encircling or penetrating masonry may disrupt or fracture such masonry by increase in the mass of the tie-rod or band as the result of the oxidation of the metal.

Examination of the expression FeH_6O_6 shows that each atom of metallic iron converted to rust is in combination with twelve atoms of hydrogen and oxygen. It is also easy to realise that the consequent increase of bulk is very great, and represents a practically irresistible force. In fact, it was the enlargement of iron ties in the same way that nearly destroyed the famous façade of St. Mark's, Venice.

To illustrate the destructive effects of the oxidation of metals, let us take the case of an unprotected wrought-iron lattice bar, 4 in. by 1 in., exposed to the air of a city, in which the aqueous proportion in the atmosphere is high, as are most of our towns in which moisture is added by the burning of hydro-carbonaceous coals. Calculating by the writer's formula given in Molesworth * it will be found that the complete oxidation of the whole of the metal will require 110 years, so that in a period of fifty-five years only one-half the original material will remain. In situations where the metal is exposed to specially destructive gases, the process of decay may be still more rapid. For example, it is said that some parts of the ironwork at Charing Cross Station have already been reduced to less than one-half the original thickness, after less than forty-five years' service, and in spite of paint.

Such a statement permits one to realise the extent of the undermining influence of rusting action during a period of years in sapping the strength of metal, upon which many valuable lives may depend. If metal be subject *pari passu* to vibration, its entire molecular structure may be rearranged, culminating in the disappearance of the fibrous character, and in its place the establishment of the crystalline structure characteristic of cast-iron, and the corresponding reduction of tensile strength. In calculating the effect of time and work in a metallic bar exposed to the effects producing vibration, both of the influences described should always be taken into account.

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* Molesworth's Pocket Book, 22nd edition, p. 32 ; 25th edition, p. 42.

SPECIAL CAUSES FOR CORROSION.

Other causes, besides the chemical action of oxygen, water and acids, may result in the corrosion of metals. For example, if iron and steel of different densities are brought into contact with each other, the less dense of the two is more liable to rust than the other.

Metals of electrical polarity opposite to those of iron and steel, either reduce or accelerate the process of rusting or oxidation. For instance, metals that are electrically positive in relation to iron and steel, preserve the latter more or less, and at their own expense. Zinc being positive in relation to iron and steel, the latter metals gain by contact with zinc, which suffers in like proportion. On the other hand, lead is negative in polarity relationship to iron and steel, and the oxidation of the latter is accelerated by contact. The same effect also applies to copper, brass, and more especially to gun-metal, which should never be brought into contact with iron and steel when exposed to an oxidising environment, except under strict and sustained supervision.

If any one requires ocular proof of the effect of negative polarity, let him examine some old iron railings embedded in lead, and he will find striking evidence of its existence in the attenuated character of the iron near the point of contact with the lead.

THE IMPORTANCE OF PRESERVATIVES.

It is now some fifty years since the completion of many of the metallic structures associated with the building of our railroads, and although, fortunately, the margin of safety adopted by the old school of engineers was high, it behoves the supervisors of our oldest railway structures to keep a vigilant watch over the metallic structures under their care, and which were built in the early days of the Railway Era.

The importance of preserving iron and steel from the strenuous efforts of oxygen and other agents, to restore them to their native condition of iron oxide or carbonate in which they are found, has been recognised by engineers and chemists ever since the beginning of the iron and steel age. It is particularly important that these metals should be adequately protected when employed in the construction of modern habitable structures, in which the metal framework forms the weight-bearing anatomy of the structure which may be the everyday habitat of hundreds of human beings.

That most building stones and bricks, as also terra-cotta, are not impervious to the flow of air and the penetration of moisture is well known, thanks to the classic researches of Pettenkofer and others. Therefore, it is only to be expected that unprotected steel columns, or beams embedded in brickwork, masonry, or terra-cotta, will suffer from the action of rust, more particularly when located in the basement and foundations of a building; hence the necessity for really efficient protective material becomes perfectly clear.

CEMENT AND CEMENT CONCRETE AS EFFICIENT PRESERVATION.

During the writer's examination of the steel-frame system of building construction in the United States, he inquired into the methods in use for preserving from oxidation the iron and steel employed in buildings. He learned that a covering of high-class Portland cement had proved an excellent preservative for iron and steel employed in the most trying situations. It had been found that the expansion and contraction of the metal, owing to temperature variations, had synchronised with the expansion and contraction of the Portland cement, and that the removal of steel columns and beams after some years of service had shown that the coating of Portland cement had effectively preserved the metal from any appreciable oxidation or rusting effects.

Further demonstration of the preservative qualities of Portland cement is furnished by instances cited by various speakers, in a discussion on the preservation of materials, at a meeting of the American Society of Civil Engineers.* The following facts are abstracted from the record of this discussion :—

Mr. Rudolf P. Miller stated that, on the demolition of a modern steel skeleton building four years old, in New York City, the floor beams and girders, encased in cinder concrete, were found to be remarkably free from rust. Where there was any, it was in very small patches, more generally on the rivet heads, and it was probably there before the floor arches were placed.

Mr. George Hill, while admitting his interest in a paint business, expressed the conviction that steel which had been properly embedded in concrete remained absolutely unimpaired and perfect in its condition. He mentioned a series of experiments made by him for the representatives of the Melan system of reinforced concrete, in which steel bars were embedded into stone concrete. After exposure to the weather for from sixty to ninety days, wherever the concrete had been in contact with the steel, no rust showed at all. The steel was not painted, and showed bright; but wherever there were voids in the concrete, due to the use of rather dry cement with a stone aggregate, rust had set in.

In the same volume of the Proceedings it is recorded that Mr. George W. Dickie, of the Union Iron Works, San Francisco, had used Portland cement for many years, with very satisfactory results, for the protection of iron and steel from corrosion. As an example, it was stated that while recently repairing the iron hull of a ship, Mr. Dickie had occasion to remove a portion of the cement floor which had been laid some forty years before, and the iron beneath the cement lining was then found to be absolutely free from rust. The fact that the cement was exposed to the most active kind of corrosion—that caused by sea water—makes this experience a very strong argument in favour of Portland cement as a preservative of steel.

Turning now to experimental testimony, we may refer to the conclusions drawn by Professor Norton from his extensive series of investigations extending from

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* Proceedings American Society Civil Engineers. Vol. XXIX. No. 3.

1901 to 1904. These researches demonstrate conclusively that neat Portland cement, even in thin layers, is an effective preventive of rust, and that cement concrete is equally effective if without voids or cracks and imperfect contact with the metal, but that it is of the utmost importance that the metal should be perfectly clean when bedded in concrete.

The absolute necessity for preventing the presence of voids near the metal was clearly established by Professor Norton, and is also indicated by the experience of Mr. Hill, stated before the American Society of Civil Engineers.

This is a point that should always be borne in mind, and another is that the cement used must be of really good quality. If these precautions are neglected there will certainly be risk of corrosion. On the other hand, if Portland cement grout or concrete of approved quality be properly applied there is not the slightest reason for fearing the corrosion of the iron or steel embedded in or covered by the material.

It is very important that the absolute safeguard offered by Portland cement should be universally recognised, especially in view of the recent injudicious repetition of rumours to the contrary.

The chemical reactions underlying the setting of Portland cement may to some extent explain its preservative influence. Any ordinary moisture present on the metal owing to the application of the cement will be absorbed in the setting process, so that one active element of oxidation will be removed. As the alkaline character of the cement serves to neutralise any acid, another destructive agency is counteracted. Further, as Portland cement is practically impervious to the penetration of air, oxygen cannot gain access to the metal to establish and maintain the process of corrosion.

(*To be concluded*)

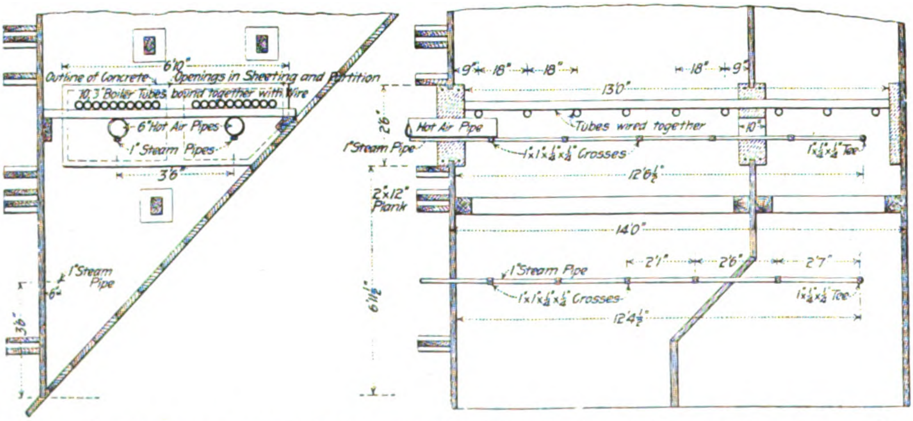


FIG. 3.—DETAILS OF ARRANGEMENTS FOR HEATING CONCRETE MATERIALS STORAGE BINS.

Safeguards against Freezing
.. IN ..
Concrete Building Construction.

The importance of guarding against frost is somewhat underrated by contractors in charge of concrete work during the winter months, and we thus present some particulars of the arrangements made in connection with some extensive building operations at Rochester, U.S.A. These particulars are published by the courtesy of the "Engineering News" of New York, and we desire to call special attention to the engravings from the working drawings, which have been carefully figured, as a guide to those who may wish to adopt similar safeguards.—ED.

THE vital necessity of absolute soundness in reinforced concrete beams and columns renders essential the most thorough precautions against frost when building is done in winter. This truth is fully realised by the more experienced builders in reinforced concrete, and they have given the subject of safeguards against freezing during construction very careful thought. To exemplify the extent and the expense of the precautions deemed justifiable in important work, we illustrate and describe here the means adopted to prevent damage by frost in constructing the shops of the Foster-Armstrong Piano Company, at Rochester, N.Y. These buildings were constructed during the severe winter of 1904–5 at temperatures often below zero, and the methods of protection adopted proved entirely successful. The same methods have also worked successfully in other buildings, and notably in the construction during the past winter of the addition to the works of the Pacific Borax Company, at Constable Hook, N.J. They have been developed as the result of several winters' work on important structures by Mr. E. L. Ransome, Assoc. Am. Soc. C.E., under whose design and supervision the buildings named were constructed. We are indebted to Mr. Ransome and his assistant engineer, Mr. F. V. Lawrence, who worked out the details of the apparatus, for the information from which this description has been prepared.

The new works of the Foster-Armstrong Piano Company comprise six main buildings, of which one is two stories high and 80 ft. by 450 ft. in plan, with an 80 ft. by 120 ft. wing; and five are duplicate five-story buildings 50 ft. by 200 ft. in plan. The general arrangement of these buildings is shown by the diagram plan Fig. 1. They are all built entirely of reinforced concrete, in which the Ransome twisted bars were used. The total floor area in these buildings was nearly half a million square feet. The system of safeguards against freezing comprised: (1) the preparation of the concrete materials so as to delay the action of frost; (2) the housing-in of the work under construction; and (3) the artificial heating of the enclosed space.

PREPARATION OF CONCRETE INGREDIENTS.

The preparation of the concrete ingredients comprised the heating of the sand and gravel, and the addition of salt to the mixing water so as to lower its freezing point. These are both time-honoured expedients, and the only point of novelty in their use here is in the character and management of the plant adopted for handling the large quantities of materials used daily. The daily consumption of sand and gravel was about 50 cubic yards and 100 cubic yards respectively.

To provide storage for the sand and gravel, a bin 16 ft. square in projected plan was constructed with vertical sides and a sloping bottom, as shown in Fig. 2. This

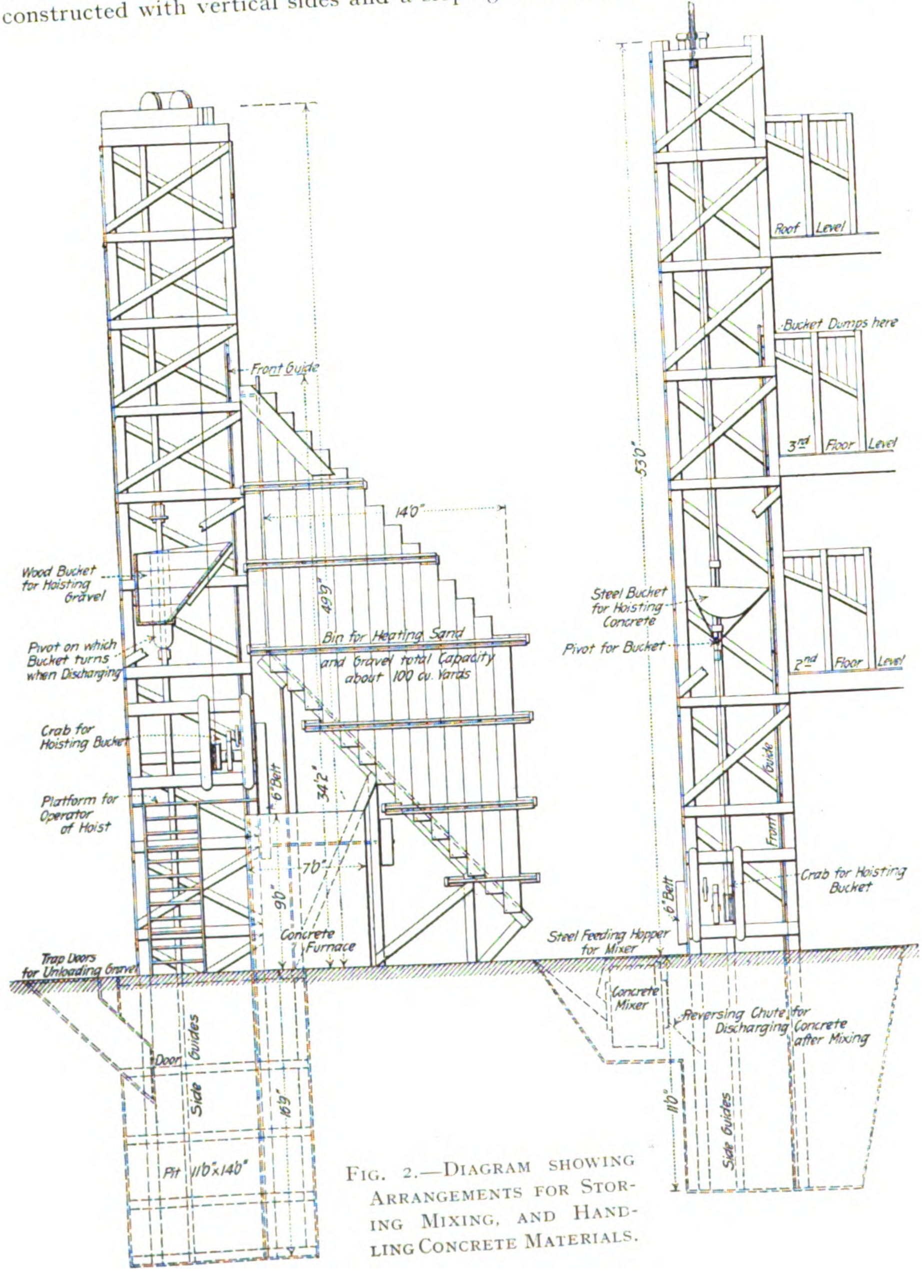

Front Guide
14'0"
49'9"
Bin for Heating Sand and Gravel total Capacity about 100 cu. Yards
Wood Bucket for Hoisting Gravel
Pivot on which Bucket turns when Discharging
Crab for Hoisting Bucket
Platform for Operator of Hoist
6' Belt
34'2"
7'6"
9'6"
Concrete Furnace
Trap Doors for Unloading Gravel
Door
Side Guides
16'9"
Pit 11'6"×14'6"
Roof Level
Bucket Dumps here
3rd Floor Level
53'0"
Steel Bucket for Hoisting Concrete
Pivot for Bucket
2nd Floor Level
Guide
Front
Crab for Hoisting Bucket
6' Belt
Steel Feeding Hopper for Mixer
Concrete Mixer
Reversing Chute for Discharging Concrete after Mixing
11'6"
Side Guides

Fig. 2.—Diagram showing Arrangements for Storing Mixing, and Handling Concrete Materials.

bin was thoroughly braced by interior struts, and was divided by a vertical partition into a large and a small compartment for gravel and sand, respectively. These materials coming to the work are dumped by means of a chute into a wooden bucket which moves up and down in a guide frame located at the rear of the bin. The bucket is hoisted by means of a crab and is so hung out of balance that, when hoisted clear of the restraint of the front guide, it dumps automatically. The front guide, as will be seen, is discontinued just above the bin top so that, when it overturns, the contents discharge into the bin.

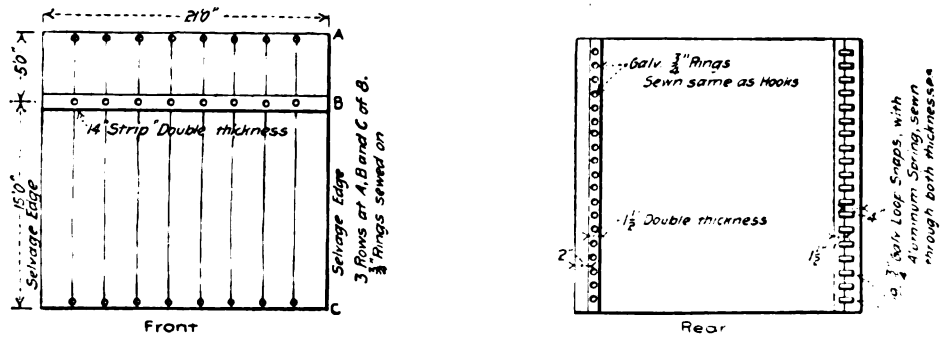

21'0"
5'0"
15'0"
Selvage Edge
A
B
C
1/4 Strip Double thickness
Selvage Edge
3 Rows at A, B and C of 3/4" Rings sewed on
Front
Galv. 3/4" Rings
Sewn same as Hooks
1 1/2" Double thickness
2"
1 1/2"
4"
3/4" Galv. Loop Snaps, with Aluminum Spring, sewn through both thicknesses
Rear

FIG. 5 AND 6. DETAILS OF CANVAS CURTAINS FOR ENCLOSING SIDE WALLS.

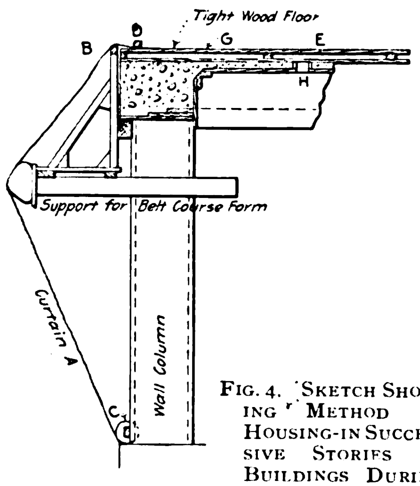


FIG. 4. SKETCH SHOWING METHOD OF HOUSING-IN SUCCESSIVE STORIES OF BUILDINGS DURING CONSTRUCTION.

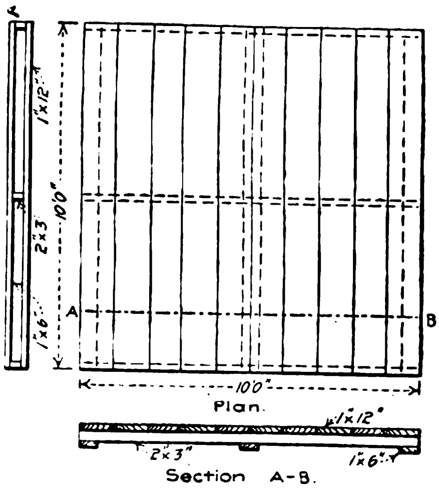


FIG. 6. DETAILS OF WOODEN PANELS.

The heating of the sand and gravel is done within the storage bin, and the drawings of Fig. 3 show the arrangements devised for this purpose. The platforms or gratings of tubes set close together and supported, as shown, caused V-shaped cavities to be formed beneath in the gravel and sand. Into these cavities penetrated, through one end of the bin, pipes from a hot-air furnace and from a steam boiler. The hot-air pipes merely pass through the wall, but the steam pipes continue nearly to the opposite side of the bin, and are provided with open crosses at intervals along their length. Where the pipes penetrate the wall and partition, concrete slabs are inserted. In addition to the conduits described, there is a small pipe for steam located below and near the bottom of the bin. The hot-air pipes connect with a small furnace, and air was forced through them by a Sturtevant No. 6 blower. The arrangement described sufficed, although the top of the bin was open to snow and wind, to keep the gravel and sand from freezing.

The drawings of Fig. 2 show the relation of the gravel and sand bins to the concrete mixer. In mixing the concrete, the water was heated to about 90 deg. Fahr. and salt added in about the proportion of 6 lb. per barrel of cement. The water was heated by blowing live steam through perforated pipes in the storage tanks. There were two of these, each of 1,000 gallons capacity; one was used for fresh water and one for saturated solution of salt water. The storage tanks discharge into a measuring tank, which fed the salt water to the mixer. The method of taking the concrete from the mixer to the several floors of the building is indicated by Fig. 2. The mixer was a Ransome No. 3, and its output was 150 cubic yards per day.

HOUSING OF CONCRETE WORK.

Each building as it was constructed was housed in by a temporary structure of timber and canvas. The character of the protecting structure, and the method of erecting it, are best explained by referring to the sketches, Figs. 4 to 6. Fig. 4 shows one of the first floor wall columns and a portion of the second floor wall girders and floor system. It will be seen that the open sides are enclosed by canvas curtains and the

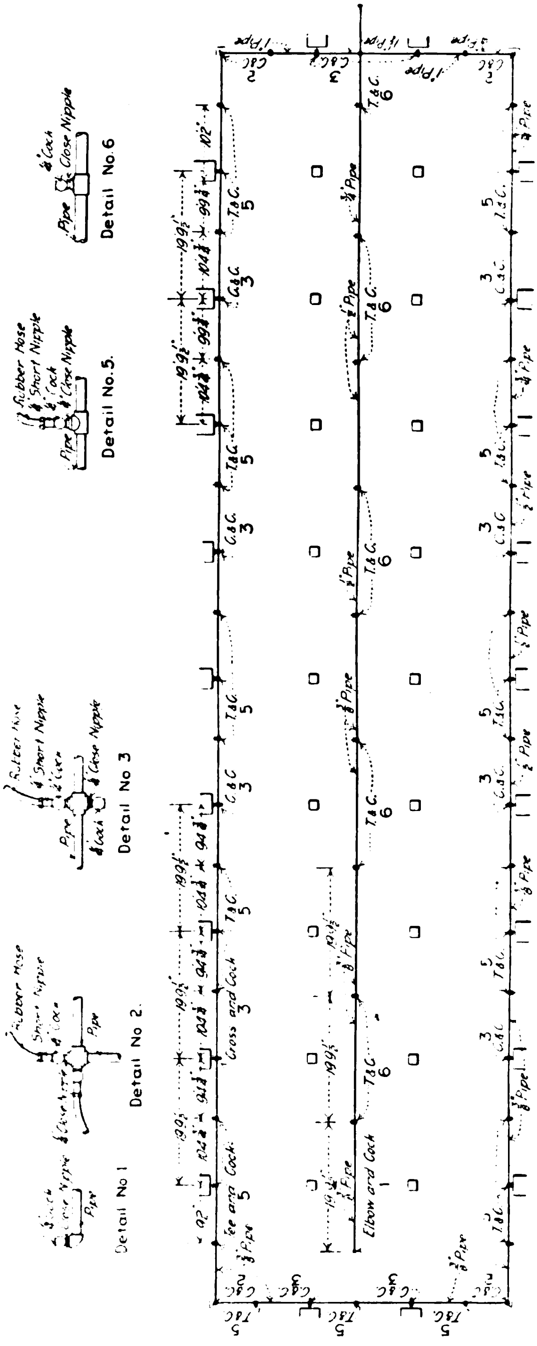


FIG. 1. DIAGRAM OF WORKS SHOWING SYSTEM OF PIPES FOR CONVEYING STEAM HEATS TO BUILDINGS DURING CONSTRUCTION.

floor covered with timber shutters. The curtain, A, Fig. 4, is held by tying-rings to a continuous string piece, B, the upper portion or flap, D, being held down by a metal rod or other heavy object so as to lap over the floor covers, E. At the bottom the curtain is attached to the string piece, C. The sketch shows how the curtain adjusts itself to irregular projections such as the support for the belt course forms; to prevent the canvas from tearing on the timbers these are cushioned by rolls of bagging or other suitable material. The drawings of Fig. 5 show the fabrication of the individual curtains so clearly as to demand no description.

The construction of the wooden floor panels is shown by Fig. 6. They are so designed that a hollow space is left between them and the floor. To provide for circulation of air in this space, holes are formed through the concrete floor slab as shown at H, Fig. 4. The drawing, Fig. 6, shows a 10 ft. by 10 ft. panel, made of 12 in. by 1 in. boards nailed to the edges of 2 in. by 3 in. battens, the free edges of which have attached 6 in. by 1 in. boards to stiffen the ribs and give a good bearing on the green concrete.

HEATING THE ENCLOSED SPACE.

The heating of the space enclosed by the housing was accomplished by means of coke fires in braziers and by a system of steam pipes from a central boiler. The plan, Fig. 1, shows the location of the boiler, and the steam pipes which lead from it, to the several buildings. Fig. 7 shows the arrangement of the steam piping in one of the buildings; this system was duplicated for each floor. The idea of the arrangement is to discharge live steam into the enclosed space and into the hollow wall columns by means of short lengths of hose entered into holes in the column shells. The details of the various connections are shown by the drawings. The open fires were scattered throughout the floor area, and were simply fires of coke in home-made braziers of reinforcing metal. Each brazier held about 5 cubit feet of coke, and ten of them were used for each enclosed floor, 50 ft. by 200 ft. by 13 ft. high. The ten braziers and the steam piping together kept the temperature at about 80 deg. Fahr. in the space below the floors, and at about 40 deg. in the space between the floor top and its board covering. These temperatures were maintained when the temperature outside ranged from zero to 10 deg. above zero.

In construction the columns were concreted first, and then the belt courses and the floor system. As soon as the belt courses were completed, the canvas wall curtains were hung, and likewise the floors were covered with the wooden panels as fast as the concreting was finished. The concrete was deposited regardless of the temperature, it being the theory that once laid, and whether frozen or not, it would be kept continually above freezing temperature by the artificial heating arrangements until it had thoroughly set. The theory worked out perfectly, and no damage resulted to any of the work because of frost.

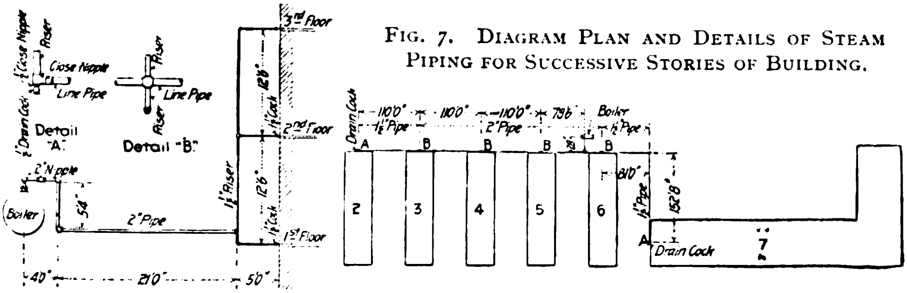


FIG. 7. DIAGRAM PLAN AND DETAILS OF STEAM PIPING FOR SUCCESSIVE STORIES OF BUILDING.

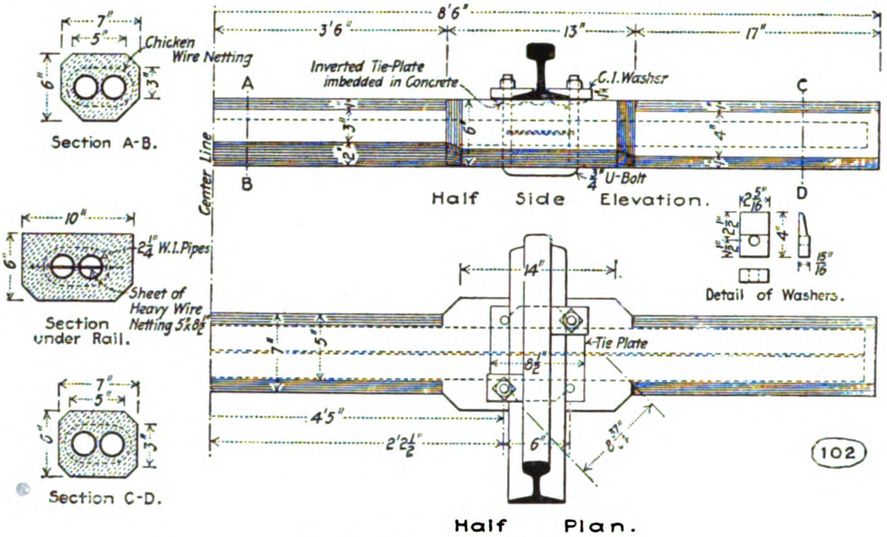


FIG. 1. THE CAMPBELL TIE.
(Elgin, Joliet & Eastern Ry.)

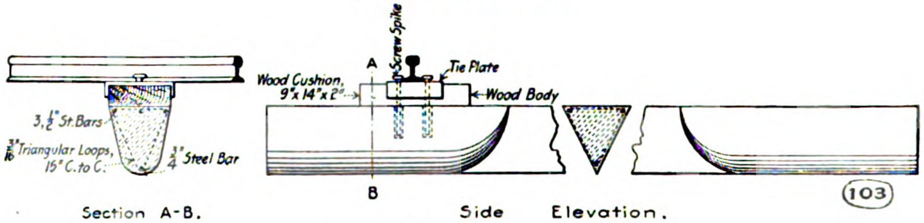


FIG. 2. THE PERCIVAL TIE.
(Galveston, Houston & Henderson Ry.)

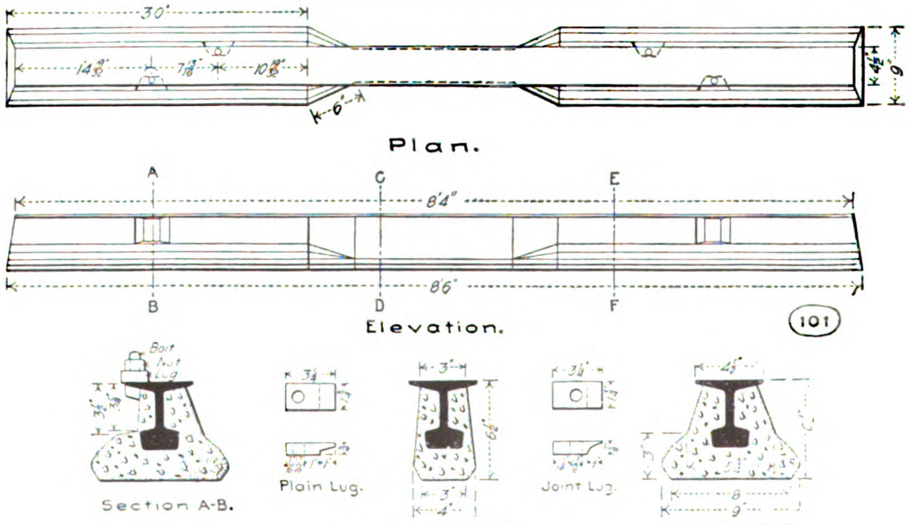


FIG. 3. THE BUHRER TIE.
(Lake Shore & Michigan Ry.)

NEW USES OF CONCRETE

AT HOME AND ABROAD.

Under this heading reliable information will be presented as to new uses to which concrete and reinforced concrete are put, with data as to experience obtained during the experimental stage of such new applications of these materials. The use of reinforced concrete as a substitute for timber in exposed positions is one of the questions of the moment. Railway sleepers, telegraph posts, fence posts, etc., of concrete are being tried, and the new railway sleepers are dealt with in this issue.—ED.

REINFORCED CONCRETE RAILWAY SLEEPERS.

By the courtesy of the *Engineering News*, we present some particulars of Reinforced Concrete Railway Sleepers, under investigation in the United States, where, having regard to the cheapness of timber, the serious consideration given to the question of their introduction is particularly remarkable.

The ties, of which we present illustrations are known as the Campbell Percival and Buhrer ties respectively, of which the latter includes for the use of old material, *i.e.*, old rails for reinforcements.

Campbell Tie.

This design is the invention of Mr. R. B. Campbell, General Manager of the Elgin, Joliet and Eastern Railway, who informs us that 140 ties have been in use from eight to twelve months, while 1,000 more are being made and will be put in use under heavy traffic on the Chicago, Lake Shore and Eastern Railway (of which also Mr. Campbell is general manager).

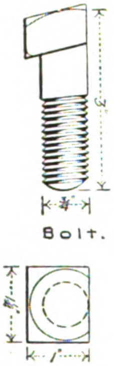
The tie is approximately rectangular, with bevelled corners, but at the rail seat the top is level for the full width, and has embedded in it a flat tie-plate, consisting of a grooved and shouldered tie-plate laid upside down. This plate is 8½ in. square. The ties are reinforced by two 2¼ in. wrought-iron pipes (scrap boiler tubes) and by an oval wrapping of chicken wire, as shown in the sections. At the rail seats also, each pipe has a ¼ in. slot, 6 in. long, cut in the side, and in this is inserted a sheet of heavy wire netting 5 in. by 8½ in. Each rail rests upon a flat tie-plate and is secured by a ¾ in. U-bolt having a spread of 8¾ in. placed diagonally. A $\frac{13}{16}$ in cast washer, 4 in. by $2\frac{5}{16}$ in. on top, is slipped over each end of the bolt and held down upon the rail base by a nut. The ties are 6 in. deep and 7 in. wide, except that at the rail seat the width is increased to 10 in. The length is 8 ft. 6 in. The concrete is composed of 1 part Portland cement, 2 parts sand, and 3 parts of crushed stone, screened gravel or crushed slag. The average weight is 356 lb., including 35 lb. of steel reinforcement, and the ties can be made and sold at a price of $1.50 to $1.75 each. The tie is in an experimenta stage, and 19 have failed owing to faulty mixture, the sand containing too much loam; but it is believed that the tie will prove a success.

Tests of several of these ties were made in

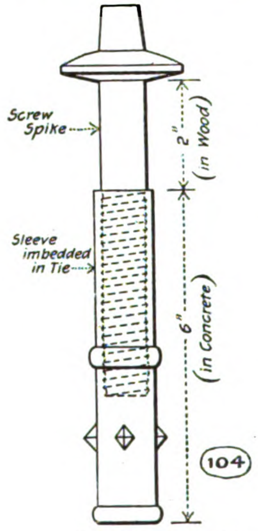
TABLE I.—TESTS OF REINFORCED CONCRETE CAMPBELL TIES.—(Load applied at Centre.)

Tubes No.	Tubes Diam. No.	Weight of Tie. lbs.	Age of Tie. days	Composition of Concrete (1 cement).	Load Cracked at lbs.	Load Broke at lbs.	Deflection At Crack in.	Deflection At Break in.
1	3	..	119	2 sand, 3 bank gravel	..	4,000	..	.109
1	3	..	196	2 sand, 3 wash. bank gravel	4,000	5,000	.184	.456
2	2¼	..	117	4 Limestone screenings	..	5,000	..	.435
1	3	..	195	2 sand, 3 wash. bank gravel	4,000	5,400	.209	.438
2	2¼	385	120	3 limestone screenings	4,000	5,400	.195	.435
2	2¼	..	116	2 sand, 3 wash. bank gravel	4,400	5,400	.198	.440
2	2¼	293	152	2 sand, 3 bank gravel	2,000	5,600	.040	.320
2	2¼	..	116	2 sand, 3 bank gravel	4,800	5,800	.152	.300
2	2¼	401	116	3 crushed stone	5,200	5,800	.272	.425
2	2¼	364	147	2 sand, 3 slag	4,800	7,000	.183	.421
1	3	..	94	3 crushed stone, 2 lime, screenings ..	..	7,800	..	.511
1	3	311	195	2 sand, 3 wash. lake grave	7,200	9,800	.245	.415
				(Load applied at ends.)				
2	2¼	355	200	7 crushed stone	10,000	11,400	.265	.465
2	2¼	..	196	2 sand, 3 wash. lake gravel	8,200	13,000	.084	.104
2	2¼	383	126	7 limestone screenings	..	14,200	..	.572

a Riehle testing machine. All the ties were 7 in. by 7 in. and 8 ft. 6 in. long, and fitted with tie-plates. In a crushing test, with the load applied at the rail seat, one tie developed the first crack at 80,000 lb., and crushed at 100,000 lb. Twelve ties were placed inverted, with their tie-plates resting on blocks 5 ft. c. to c., and had the load applied at the middle. Three others were placed in the same way, but carried blocks at the ends on which rested a beam to which the load was applied. The ties were made of different kinds of concrete, and reinforced with one and two tubes. The results are given in Table I.



Rail Fastening for Buhrer Tie.



Rail Fastening for Percival Tie.

Percival Tie.

This tie, shown in Fig. 2, is the invention of Mr. H. E. Percival, 1316 Ave. I, Galveston, Tex. It is 8 ft. long, triangular in section for 4 ft. at the middle, while the end portions have the sides more nearly vertical and the bottom rounded. It is 9¼ in. wide on top and 10 in. deep. The reinforcement consists of three ½ in. Johnson corrugated steel bars in the top and a single ¾ in. bar in the bottom; over these are triangular stirrups or loops of $\frac{3}{16}$ in. wire, placed 16 in. apart. Each rail rests on a 2 in. cushion block of treated wood, 9 in. by 14 in. The weight of the tie is about 400 lb. The fastenings, Fig. 3, consist of ¾ in. screw spikes entering sleeves or sockets of babbit metal embedded in the concrete. Other designs for fastenings by clamps, etc., have been made; in one of these, the ends of the tie are hollow, and receive the nuts for bolts, which are screwed in from above, the nut being held by a wrench. In June last, the Galveston, Houston and Henderson Railway laid 25 of these ties at Galveston, Tex.; they are spaced 20 in. c. to c. in shell and sand ballast and carry 66 lb. rails. Mr. J. J. Powers, Roadmaster, reports that the fastenings are satisfactory.

Buhrer Tie.

The ties in question are of the pattern invented by Mr. C. Buhrer, Roadmaster of the Lake Shore and Michigan Southern Railway, at Sandusky, O. The design is shown in the accompanying cut, and it will be seen that the reinforcement consists of a length of 65 lb. scrap rail, inverted; the flange forms the seat for the track rail and the attachment for the fastenings. It is proposed, however, to use a rolled section which will weigh about 80 lb. The ties as now made weigh about 400 lb. (concrete, 235 lb.; steel, 165 lb.). In some of the ties the concrete proportions are 1 part cement to 4 parts gravel; others have 1 part cement, 1 part fine-washed limestone, and 3 parts ½ in. washed limestone. The labour, cement, gravel and stone cost about 50 cents per tie, but with machine mixing and machine pressing it is thought that the cost for labour could be reduced to about eight or ten cents per tie. The cost of the scrap rail depends upon its market value. Besides ties which have failed on this railway, there have been some failures on the Pennsylvania Lines, where the ties were placed in the westbound main track on a six degree curve. Other Buhrer ties on the same road, near Toledo, are giving good service. Over 5,000 of these ties have been made, and 4,200 are in use, as follows:—

Lake Shore and Michigan Southern Ry. (Elkhart Div., 1,000; Old road, 1,003; Sandusky Div., 710; Chicago Div., 230)	2,943
Pennsylvania Lines	450
Lakeside and Marblehead Ry.	550
Sandusky City water-works track	120
Ann Arbor Ry.	77
Lake Erie and Western Railway	24
Wabash Ry.	25
Chicago and North-western Ry.	15
Total in use	4,204
Made, but not yet in use	1,000
Total	5,204

TESTS WITH CONCRETE

AT HOME AND ABROAD.

We consider that the absence of reliable information as to the various tests carried out with concrete both at home and abroad has frequently led to misconceptions as to the qualities of this material, and we shall thus for the present accord considerable space to the presentation of authentic data that may be of service to those employing concrete in its various forms. The tests which will particularly call for our attention are those relating to strength, fire-resistance, and waterproofing.—ED.

VARIOUS CONCRETE AGGREGATES UNDER FIRE AND WATER TEST.

A fire test with a floor comprising seven concrete bays, each bay being of a different aggregate in common use, has been recently undertaken by the British Fire Prevention Committee, and the report on the test has been issued.*

The test was one of three hours' duration, at temperatures reaching 1,900 deg. Fahr., followed by the application of water for a period of two minutes from a steam fire engine, the bays being under a load of 2 cwt. per foot super during the test.

Each bay had a thickness of 5½ in., and the soffit exposed was 2 ft. 7 in. by 10 ft., each end of the bay resting on the containing walls of the testing chamber, whilst lengthwise the bays were supported by joists encased with coke breeze concrete.

The concrete aggregates under test were as follows:—

1. Slag Concrete.
2. Broken Brick Concrete.
3. Granite Concrete.
4. Burnt Ballast Concrete.
5. Coke Breeze Concrete.
6. Clinker Concrete.
7. Thames Ballast Concrete.

In order to indicate the results of this test in the simplest manner possible, a diagram and table are presented which will indicate clearly the arrangement of the bays under test, the aggregates employed in each bay, and the net results of the test.

In preparing the concrete, the cement used was identical, and known as the "Ferrocrete" brand by a British maker. An equal amount of water was used in mixing for each bay. The sand for each bay was of identical quality, and the different bays were all completed within three days, so that the difference between the setting and drying between the first and seventh bay was only about 60 hours; the time actually allowed between completion of the last bay and the actual test being 40 days (autumn weather).

The test was conducted by a Sub-committee, comprising—

Mr. Max Clarke, F.R.I.B.A. (Directing Member); Mr. B. Dicksee, F.R.I.B.A. (District Surveyor, Stoke Newington); Mr. J. Herbert Dyer (Vice-President National Fire Brigades' Union); Mr. E. J. A. Fulkes (Surveyor Royal Insurance Company); Mr. William Grellier, F.R.I.B.A. (Dist. Survr., Clapham); Mr. Matt. Garbutt, A.R.I.B.A., A.M.Inst.C.E. (Architect to the Metropolitan Railway); Mr. A. T. Walmisley, M Inst.C.E. (Engineer, Dover Harbour Board); Mr. Oswald C. Wylson, F.R I.B.A.; Lt.-Col. Winn, R.E., A Inst.C.E

There was also a very large attendance of public officials representing Government Departments.

Mr. Max Clarke, F.R.I.B.A., signs the report on behalf of the sub-committee conducting the test; Mr. James Sheppard, A.Inst.E.E. (Chief Surveyor North British and Mercantile Insurance Company), signs it on behalf of the General Testing Arrangements Sub-committee; and Mr. Ellis Marsland (District Surveyor, Camberwell), Gen. Hon. Secretary, on behalf of the Executive.

The report, as is usual with these reports, contains facts only; but in an official prefatory note, Mr. Clarke states that, in his opinion "the test did not go far enough to draw definite conclusions, except to show the entire unreliability of Thames ballast concrete as a suitable material for this method of construction," and he goes on to say "that as to the aggregates other than Thames ballast, no undisputable statement can as yet be made."

The test which is one of the highest importance to all users of concrete, has certainly taught a valuable lesson, but it is to be hoped that it will be repeated on some more elaborate scale, and that other aggregates will also be tested, such as the very common aggregate of broken brick and coke-breeze mixed.

The illustrations presented have been loaned by the courtesy of the Committee.

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* "Red Book" No. 101, 2s. 6d., 8vo, illustrated.

TABULATED RESULT
OF
THE OFFICIAL FIRE AND WATER TESTS
WITH
SEVEN BAYS OF DIFFERENT CONCRETE AGGREGATES.

Duration of test: three hours, with temperature rising to 1900 deg. Fahr., followed by the application of water from a steam fire engine (from below), two minutes.

GENERAL CONDITIONS	OBJECT UNDER TEST.			RESULT.	REMARKS.	
	Description of Bay.	Aggregate.	Parts *by vol.*	SUMMARY OF EFFECT.	Special.	General
The soffit of each bay exposed to fire and water measured 10 ft. by 2 ft. 7 in., and each bay was 5½ in. thick; the distributed superimposed load on each bay was 2 cwt. per foot super.	BAY No. I. SLAG CONCRETE	Blast furnace slag Clean sand Cement	3 2 1	*Top:* Slab cracked across in two places. *Underside:* Curved downwards ¼ in.; slight cracks visible	The blast furnace slag was from the Islip Ironworks, broken to pass a 1½ in. ring	The sand used was identical throughout, namely, pit sand; the cement was identical throughout, namely, British Portland "Ferrocrete" cement of very fine grinding; 1·2 gallons of water were used to each cubic foot of concrete (approximately 20 per cent. of water by volume). The centering under each bay was struck fourteen days after completion: the time allowed for setting and drying was forty days.
	BAY No. II. BROKEN BRICK CONCRETE	Broken brick Clean sand Cement	3 2 1	*Top:* Slab cracked across in three places; slight curve downwards *Underside:* Curved downwards ¼ in.; slight cracks visible	The broken brick was London stock brick, broken by hand to pass a 1½ in. ring	
	BAY No. III. GRANITE CONCRETE	Broken granite Clean sand Cement	3 2 1	*Top:* Slab cracked across in three places; curved downward about ½ in. *Underside:* Curved downwards ½ in.; no cracks visible; about 1 in. washed off by water	The broken granite was Guernsey granite chips, crushed to pass a ¾ in. ring	
	BAY No. IV. BURNT BALLAST CONCRETE	Burnt ballast Cement	5 1	*Top:* No cracks; not curved downwards *Underside:* Not curved downwards: no cracks visible; about 3 in. washed off underside (in parts) by water	The burnt ballast was from the neighbourhood of Child's Hill, clay burnt with slack coal, broken to pass a 1½ in. ring	
	BAY No. V. COKE BREEZE CONCRETE	Coke breeze Cement	5 1	*Top:* No cracks; not curved downwards *Underside:* Not curved; no cracks visible: about 1 in. washed off underside (in parts) by water	The coke breeze was from the retorts of a London gas company, broken to pass a 1½ in. ring (free from fine dust)	
	BAY No. VI. CLINKER CONCRETE	Furnace clinker Clean sand Cement	3 2 1	*Top:* Slab cracked across in two places; curved downwards about ¾ in. *Underside:* Not curved; one slight crack visible; pitted in places about 1 in. deep by water	The furnace clinker was raking from large furnaces, broken to pass a 1½ in. ring (free from fine dust	
	BAY No. VII. THAMES BALLAST CONCRETE	Thames ballast Clean sand Cement	3 2 1	*Top:* Slab cracked across in very many places; curved downward about 2 in. *Underside:* Curved downward 1½ in., and bad cracks all over in all directions, mainly longitudinally; much washed off by water	The Thames ballast was dredged from the river Thames, to pass a 1½ in. ring	

NOTE.—The steel joists supporting the slabs were encased with concrete, as used in Bay No. V. (but finer), 2 in. thick, and plastered ½ in. thick. Where struck by water, part of the concrete on each beam was washed off. No steel was exposed. The joists did not deflect. The concrete was disintegrated about 1 in. deep.

SOME EXPERIMENTS ON THE ADHESION OF STEEL EMBEDDED IN CONCRETE.

The Special Joint Commission of German Civil Engineers and the representatives of the German reinforced concrete contractors who have been carrying out various tests regarding concrete, and reinforced concrete in particular, has completed a somewhat interesting series of tests on the adhesion of steel embedded in concrete. The particulars here presented take the form of a rough translation of some extracts of the official report published in *Mittheilungen über Forschungsarbeiten* (Vol. 22).

THE REPORT.

The report states as follows :—

The coefficient of adhesion, which was to be ascertained by the investigations, is obtained by dividing the force required to move the embedded bar, either by pushing or pulling the surface of the bar when in contact with concrete. It is therefore the resistance of the bar against slipping reduced to the unit of the surface of the bar.

The results obtained from the experiments may be briefly summarised as follows :—

Surface of the Bars.

1. The adhesion on embedded bars of true prismatic shape depends upon the condition of the surface of the same, and is also influenced by deviations from their true prismatic shape.

Turned and finished bars gave about one-half of the adhesion obtained from rough bars, *i.e.*, bars in the condition as received from the rolling mill.

The value of adhesion in various finished bars of the same diameter varied only very little, thus :—

for l = 6 in., t = 149, 163, 149, 142, 149 lb. per square inch;

for l = 12 in., t = 107, 98, 98, 112, 107 lb. per square inch.

In case of rough bars, however, the variations were considerable, viz :—

for l = 6 in., t = 262, 299, 262, 269, 225 lb. per square inch ;

for l = 12 in., t = 263, 206, 195, 178, 245 lb. per square inch ;

where l = length of bar embedded in concrete,
t = coefficient of adhesion.

These variations in rough bars are influenced by the degree of roughness of surface as well as by irregularities in the prismatic shape.

In pulling out a turned or finished bar, it has occurred that after the bar has commenced to slip, a roughing of the surface takes place, which increases the adhesion or resistance against slipping far above that which was observed when slipping just commenced.

Water and Sand in the Concrete.

2. The adhesion depends in a great measure upon the amount of water which is used in mixing the concrete.

With the least amount of water with which it was possible to produce test pieces, other conditions being equal, the greatest adhesion was obtained.

With increased percentage of water the adhesion diminished rapidly ; it was found for instance, that the coefficient of adhesion with 12 per cent. of water was 544 lb. per square inch, and with 18 per cent. of water 212 lb. per square inch.

This reduction of adhesion with increasing percentage of water corresponds with the decreasing weight of the volume of concrete. For instance, concrete with 15 per cent. of water was found to weigh from 130 to 131 lb. per cubic foot, with 18 per cent. of water from 125 to 126 lb. per cubic foot, and with 21 per cent. of water 122 to 123 lb. per cubic foot, other conditions being the same.

3. Changes in the amount of sand within certain limits have no important influence on the adhesion.

Section and Length of the Bars.

4. The coefficient of adhesion in rough or unfinished round bars is greater for those of larger section, than for smaller ones ; for instance :—

for l = 6 in. and d = ⅜ in., ¾ in., 1½ in.
t = 200, 263, 394 lb. per square inch.

5. For bars of equal sectional area the coefficients of adhesion are considerably higher for flat and square bars than for round bars.

6. The adhesion decreases (barring a few exceptions) as the length of the embedded bar increases.

LAWS, RULES, AND REGULATIONS

AT HOME AND ABROAD.

The necessity of framing special regulations for the control of buildings and constructional works of concrete and of steel is being generally recognised, and new codes of rules are being issued in different parts of the world by governments, municipalities, underwriters, and estates. Important Laws, Rules, and Regulations will be published in full or in extract under this heading, for they will not only serve as a guide to those who assist in the preparation of such measures, but also to those engineers and architects who, in the absence of regulations, are anxious to safeguard the interests of their employers by specifying their work to meet the eventualities of time or unusual strain.—ED.

The New York Regulations on "Concrete-Steel Construction."

EXTRACTS.

1. The term "concrete-steel" in these regulations shall be understood to mean an approved concrete mixture reinforced by steel of any shape, so combined that the steel will take up the tensional stresses and assist in the resistance to shear.

2. Concrete-steel construction will be approved only for buildings which are not required to be fireproof by the Building Code, unless satisfactory fire and water tests shall have been made under the supervision of this Bureau. Such tests shall be made in accordance with the regulations fixed by this Bureau, and conducted as nearly as practicable in the same manner as prescribed for fireproof floor fillings in Section 106 of the Building Code.* Each company offering a system of concrete-steel construction for fireproof buildings must submit such construction to a fire and water test.

3. Before permission to erect any concrete-steel structure is issued, complete drawings and specifications must be filed with the Superintendent of Buildings, showing all details of the construction, the size and position of all reinforcing rods, stirrups, etc., and giving the composition of the concrete construction the size.

4. The execution of work shall be confided to workmen who shall be under the control of a competent foreman or superintendent.

5. The concrete must be mixed in the proportion of one of cement, two of sand and four of stone or gravel; or the proportions may be such that the resistance of the concrete to crushing shall not be less than 2,000 lb. per square inch after hardening for twenty-eight days. The tests to determine this value must be made under the direction of the superintendent of buildings. The concrete used in concrete-steel construction must be what is usually known as a "wet" mixture.

6. Only high-grade Portland cements shall be permitted in concrete-steel construction. Such cements, when tested neat, shall, after one day in air, develop a tensile strength of at least 300 lb. per square inch; and after one day in air and six days in water, shall develop a tensile strength of at least 500 lb. per square inch; and after one day in air and twenty-seven days in water, shall develop a tensile strength of at least 600 lb. per square inch. Other tests as to fineness, constancy of volume, etc., made in accordance with the standard method prescribed by the American Society of Civil Engineers' Committee may, from time to time, be prescribed by the Superintendent of Buildings.

7. The sand to be used must be clean, sharp grit sand, free from loam or dirt, and shall not be finer than the standard sample of the Bureau of Buildings.

8. The stone used in the concrete shall be clean, broken trap rock, or gravel, of a size that will pass through a three-

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* A severe 4-hour fire test (av. 1700° Fahr.) under load, followed by water from steam fire engine.

quarter inch ring. In case it is desired to use any other material or other kind of stone than that specified, samples of same must first be submitted to and approved by the Superintendent of Buildings.

9. The steel shall meet the requirements of Section 21 of the Building Code.

10. Concrete-steel shall be so designed that the stresses in the concrete and the steel shall not exceed the following limits:

	per sq. in.
Extreme fibre stress on concrete in compression ..	500 lbs.
Shearing stress in concrete ..	50 ,,
Concrete in direct compression	350 ,,
Tensile stress in steel ..	16,000 ,,
Shearing stress in steel ..	10,000 ,,

11. The adhesion of concrete to steel shall be assumed to be not greater than the shearing strength of the concrete.

12. The ratio of the moduli of elasticity of concrete and steel shall be taken as 1 to 12.

13. The following assumption shall guide in the determination of the bending moments due to the external forced. Beams and girders shall be considered as simply supported at the ends, no allowance being made for continuous construction over supports. Floor plates, when constructed continuous, and when provided with reinforcement at top of plate over the supports, may be treated as continuous beams, the bending moment for uniformly distributed loads being taken at not less than $\frac{WL}{10}$; the bending moment may be taken at $\frac{WL}{20}$ in the case of square floor plates, which are reinforced in both directions and supported on all sides. The floor plate to the extent of not more than ten times the width of any beam or girder may be taken as part of that beam or girder in comprising its moment of resistance.

14. The moment of resistance of any concrete-steel construction under transverse loads shall be determined by formulæ based on the following assumptions:—

(*a*) The bond between the concrete and steel is sufficient to make the two materials act together as a homogeneous solid.

(*b*) The strain in any fibre is directly proportionate to the distance of that fibre from the neutral axis.

(*c*) The modulus of elasticity of the concrete remains constant within the limits of the working stresses fixed in these regulations.

From these assumptions it follows that the stress in any fibre is directly proportionate to the distance of that fibre from the neutral axis.

The tensile strength of the concrete shall not be considered.

15. When the shearing stresses developed in any part of a concrete-steel construction exceed the safe working strength of concrete, as fixed in these regulations, a sufficient amount of steel shall be introduced in such a position that the deficiency in the resistance to shear is overcome.

16. When the safe limit of adhesion between the concrete and steel is exceeded some provision must be made for transmitting the strength of the steel to the concrete.

17. Concrete-steel may be used for columns in which the ratio of length to least side or diameter does not exceed twelve. The reinforcing rods must be tied together at intervals of not more than the least side or diameter of the column.

18. The contractor must be prepared to make load tests on any portion of a concrete-steel construction within a reasonable time after erection, as often as may be required by the Superintendent of Buildings. The tests must show that the construction will sustain a load of three times that for which it is designed, without any sign of failure.

INDUSTRIAL ASSOCIATIONS

AT HOME AND ABROAD.

The various Industrial Associations interested in the components necessary for the application of concrete and constructional steel are, in many instances, so extremely well organised and have command of so much talent for the scientific aspects of their work, that their proceedings are an important factor in the development of the subject. Thus, particulars will be published of such features of the meetings of bodies representing the steel and cement industries of the world as we hold may be of interest to our readers. The same applies to several of the more recently constituted associations representing the Concrete, Concrete Block, Artificial Stone and Steel Frame Building Industries of the United States and the Continent of Europe.—ED.

The Association of German Portland Cement Manufacturers.

Memoranda on the Meeting of 1905.

The annual meeting of the Association of German Portland Cement Manufacturers for 1905 was attended by representatives of 69 factories in Germany, Austria, Sweden and Denmark, and also by 339 guests. The membership includes 93 factories, representing a total annual production of 23,500,000 barrels. Although somewhat late in the day for a report on this meeting, points of such high interest were raised at this meeting that we think it advisable to refer to it, using as our authority the German Official Report and some translated extracts which appeared in the Proceedings of the American Portland Cement Manufacturers' Association.

The following are some particulars of the meeting :—

Specific Gravity as an Indication of Thorough Burning.

The new edition of the German work, " Portland Cement and its Applications in Building," having appeared, Herr F. M. Meyer called attention to an error in former editions in the statement that the specific gravity of cement is an indication of thorough burning. In several hundred experiments he has found that the highest specific gravity is obtained by burning at a temperature corresponding to Seger cone 8 to 12, at which point the cement is not yet of constant volume. On burning more strongly the specific gravity decreases, sometimes in marked degree. Roman (natural) cement, burned at comparatively low temperature, is of a higher gravity than Portland. Specific gravity is of value in detecting certain adulterations, but worthless as an indication of quality of cement or degree of burning. It was agreed to correct this error in the present edition.

The Association's Laboratory.

The results of analyses and tests of German cements, now accumulated for several years, form a most valuable material, from which interesting conclusions may be drawn. Of the 93 cements tested from samples purchased in open market in 1904, only six failed to fully pass the requirements of the " Normen."

In all, over 14,000 test pieces, briquettes, cubes and pats, were made and tested.

The Commercial Committee.

The Chairman described the efforts to secure an import tariff on cement and the causes of failure, chiefly due to the opposition of the Social Democratic party. Dr. Carl Prussing, of Hamburg, gave a gloomy account of the outlook for export of cement from Germany. The United States have practically ceased to import, except on the west coast, and cement factories are already there and under construction. Japan takes cement no longer, and the fine markets of Port Arthur and Vladivostock are closed to German cement, Port Arthur doubtless for all time ; what will happen at Vladivostock is still uncertain. The Argentine Republic keeps out German cement by government requirements that SO_3 shall not exceed one per cent. In Pernambuco, Brazil, works have been erected ; these failed to make Portland, and now make natural cement and sell as Portland (*sic.*), and there are German manufacturers who sell the manufacturers empty barrels to fill.

Addressed to the Imperial Chancellor, the following resolution was adopted :—

> "The Portland cement manufacturers of Germany, assembled in full representation, suffering strongly under over-production, express their bitter regret that the well-founded demand for protection of their national industry in the new import tariff found no recognition, in spite of the advance made by some foreign countries in the duty on cement. They hope, however, that the government will, so far as possible, promote the export of cement to foreign countries, and especially that it will support and favour the consumption of cement in our own land."

Time of Setting and Constancy of Volume.

Dr. Prussing described experiments on rise of temperature during setting of cement, as observed with a registering thermometer made by Shaffer and Budenberg; 4 kilograms (nearly 9 lb.) of cement, made into a thin paste, are used in each test. The vessel is surrounded by non-conducting material, and the temperature automatically recorded on a dial. The curves given by slow, medium and quick setting cements were very striking, and it was found that the final set of cements corresponds closely with the time of maximum temperature.

Referring to the accelerated tests for constancy of volume, the Charlottenburg Testing Station lately published the following conclusions —

> "The known accelerated tests for constancy of volume, viz.: the oven test, Heintzel's ball test, boiling test and Prüssing's press-cake test, are not adapted to give in all cases a quick and reliable verdict on the suitability of cement for practical uses."

In the same report it was urged that renewed efforts be made to devise a method which should give reliable results corresponding more closely with actual practice.

Dr. Prussing read extracts from the reports of the Committee on Uniform Tests of Cement, of the American Society of Civil Engineers, and the American Society for Testing Materials, which show that the Americans have reached the same conclusions as the Germans. He stated, however, that the committees referred to had far less influence in America than the Association of Portland Cement Manufacturers in Germany. In Germany private engineers are the only ones who ever specify accelerated tests, while government and public requirements call for the normal cold pat test only. In America, on the other hand, government and city authorities and the engineers of railways generally specify the boiling test for soundness, and the recommendations of the above committees are disregarded. In Australia, South Africa, and other countries, accelerated tests are also often required, and, for the sake of the German export trade, it was urged that the subject be further industriously studied, in the hope of finding a simple, trustworthy test which can be included in the "Normen."

The Adulteration of Cement with Slag.

Mr. Rudolph Dykerhoff gave comparative tests at one year of eight Portland cements and eight "iron-Portland cements"; the latter, as is well known, are simple mixtures of Portland cement, made from slag and lime-stone, with 30 per cent. of granulated slag. The iron-Portland cements gave lower results than the true Portland, the difference being especially marked in the case of test pieces kept in air. Relatively speaking, the air tests of iron-Portland cements, both in tension and compression, as compared with the water tests, were far inferior to those obtained with Portland cement. The tests of mixtures of Portland with 30 per cent. puzzolana (trass), instead of slag, showed similar results, the air tests being relatively low. Tests with 30 per cent. finely-ground limestone or sand, however, gave a different result, and the tests in air were generally found higher than in water, as in the case of unadulterated Portland.

The iron-Portland manufacturers claim in their advertisements that their product is a mixture of "high-lime and low-lime cement clinker." Analyses by Professor Gary show, however, that it consists simply of a mixture of normal Portland cement with ordinary blast-furnace slag. He stated that the method of parting by means of heavy solutions is not sufficient to effect a complete separation of the slag and cement, but that by the use of solutions of suitable specific gravity, *samples* of pure cement and pure slag could be separated, and from the analysis of these and of the original mixture, especially from the determination of the sulphur present as sulphides, the proportions of slag present can be closely calculated.

Revision of the "Normen."

The subject especially studied during the past year was the determination of tensile and compression strength after hardening *in air*. It is well known that the results of exclusive air hardening are very irregular; for this reason a series of tests were made at the Association laboratory, in which briquettes and cubes were kept seven days in water, then three weeks in the air of the laboratory. Most cements showed higher results than when kept 28 days in water; the differences were, however, far from uniform, some cements showing practically the same results in water hardening and in combined air and water hardening.

New Experiments on the Setting of Cement.

Professor Gary, of the Charlottenburg Testing Station, described and illustrated by diagrams the results of interesting experiments on the rise of temperature of cements while setting. The apparatus used consists of a thermometer, the bulb of which is immersed in the paste, while the shadow of the top of the mercury column is thrown by a beam of light upon a revolving cylinder carrying a photographic film. The curves obtained do not closely correspond with the beginning and end of set as shown by the Vicat needle, but it is claimed that the method gives a much more clear and uniform record of the progress of the setting process.

The Sack Question.

It is interesting to note that the Germans, with the increasing use of cement in sacks, have encountered the same troubles that are met with in the United States. It appears that jute sacks are almost exclusively used in Germany. The president stated that these suffer much more than the cotton sacks from exposure to dampness, and that careful experiments were in progress on the strength of sacks made from different materials, after repeated wetting and drying. It was urged that efforts be made to induce the railways to modify their strict requirements in regard to the return of sacks.

Sulphur in Portland Cement.

The official requirements of the Argentine Republic specify a maximum of one per cent. sulphuric anhydride, which corresponds to 1.7 per cent. calcium sulphate. This is considered a serious hardship to German exporters, since of 81 samples of German cement analysed at the Association laboratory in 1904, only two were low enough in sulphate to pass this requirement. The average percentage of sulphuric anhyhride found in the past three years is as follows:—1902, 1.62 per cent.; 1903, 1.66 per cent.; and 1904, 1.76 per cent.

This increase is supposed to be due to the growing use of the rotary kiln, since it is well-known that rotary kiln cements have more tendency to be quick-setting than those burned in vertical or ring kilns.

Eighty-one German cements analysed in 1904 contained sulphuric anhyhride as follows:—

Under 1 per cent.	2 cements.
1.0 to 1.5 per cent.	24 cements.
1.5 to 2.0 per cent.	33 cements.
2.0 to 2.91 per cent.	22 cements.

Dr. Michaelis stated that the Argentine specification is based on the old French requirement. This has now been modified, and in France 1½ per cent. SO_3 are now allowed for sea-water construction, and 3 per cent. for all other purposes.

Dr. August Dyckerhoff and the president stated that the American standard specifications allow 1.75 per cent. sulphuric anhydride; the Russian also 1.75; and the English, 2.5 per cent. The very complete experiments made in the Association laboratory and by Schindler and Michaelis all show that 2.5 per cent. SO_3 is entirely harmless. The president recommended that the "Normen" be modified to allow 2.5 per cent. sulphuric anhydride.

INDUSTRIAL NOTES.

These pages have been reserved for the presentation of articles and notes on proprietary materials or systems of construction put forward by firms interested in their application. With the advent of methods of construction requiring considerable skill in design and supervision, many firms nowadays command the services of specialists whose views merit most careful attention. In these columns such views will often be presented in favour of different specialities. They must be read as ex parte statements—with which this Journal is in no way associated, either for or against—but we would commend them to our readers as arguments by parties who are as a rule thoroughly conversant with the particular industry with which they are associated.—ED.

A REINFORCED CONCRETE SYSTEM, WITH RIGID SHEAR MEMBERS.

By M. KAHN.

At the present time so much attention is being given to reinforced concrete, that it may prove interesting to call attention to a system of reinforcement which is now being introduced into England.

The advantages of reinforced concrete over any other class of building material are so well recognised that it is unnecessary to enter into a comparison. Of course, an element of uncertainty will exist if poor material and poor concrete are used; but this must be provided against, and if the same care is exercised which is ordinarily taken in the inspection of structural steel work—there need be no lack of confidence on this score. And, again, the uncertainty as to which would fail first, the concrete or the steel reinforcement, has made the engineer and architect timid about adopting a construction of this sort; but when proper consideration is given to the method of reinforcing the concrete, this vagueness, too, can be removed, and reinforced concrete then deserves the unqualified endorsement it has received from prominent engineers of unquestionable ability.

In discussing the correct method of reinforcing concrete, we intend to bring out a few fundamental principles which are involved. The matter of vertical reinforcement is of more importance than some engineers have been willing to grant. A properly-proportioned beam, reinforced only in the horizontal plane, will fail at the centre when subjected to a load concentrated at this point. If, however, a similar beam be tested with a uniformly distributed load, it should carry an amount double that of the previous one to produce the same bending moment. Before this double load has been placed on it, the beam fails at one end by shear. Let us investigate the reason for this. Take, for example, a certain beam, as shown in Fig. 1, and consider the cross section A.A. The tension strain on each fibre below the neutral axis varies in proportion to its distance therefrom. The vertical shearing strain, however, is practically constant, and the resultant strain on any particle should be a combination of these two components, producing a line of principal tensile stress which is one of variable curvature from the bottom of the beam to the top.

If lines of principal tensile stress exist throughout a beam, it is most natural that the concrete, being weak in tension, should open up at right angles to these lines; or along the lines of principal compressive stress, which at all points are at right angles to the lines of principal tensile stress. This is what actually does occur, and we call it a failure by shear. Fig. 2 is a photograph of a test conducted by the United States Government War College. Note the manner of failure. This was first noticed by European engineers, and, in endeavouring to overcome the difficulty, U-shaped stirrups of band iron were placed vertically around the bar, the distance between them varying inversely to the ratio of the shear. Other engineers used systems wherein the reinforcement for each beam consisted of a multitude of small bars varying in length, each bar bent up at its ends to take up the shear. Such systems proved cumbersome in their manipulation, and therefore impractical. Coming back, then, to the matter of stirrups, if they are used, they should be inclined to the horizontal direction so as to lie more closely along the lines of principal tensile stress; for if they lie exactly in these lines, they then cross the actual lines of rupture at right angles, and are of maximum efficiency in holding together the concrete where its natural tendency is to open up.

Again, if stirrups are to carry stress, they should carry it into some member capable of receiving it. The bottom chord member is there for that purpose. The transfer of the stress from the stirrup to the horizontal tension member can only be accomplished by some definite connection between the two. Therefore, the shear members should be rigidly attached to the main tension member. When the stirrups are inclined and rigidly connected to the bar, the action is practically

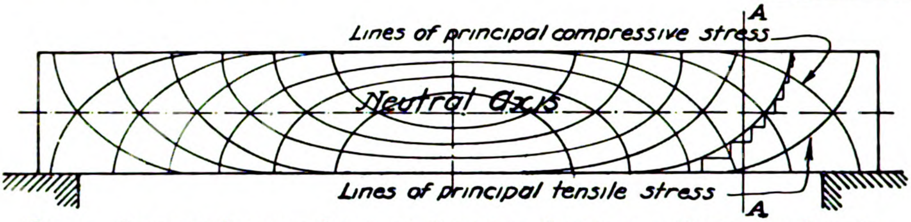
A
Lines of principal compressive stress
Neutral axis
Lines of principal tensile stress
A

FIG. 1. DIAGRAM SHOWING LINES OF PRINCIPAL STRESS IN A UNIFORMLY LOADED GIRDER SUPPORTED AT ENDS.

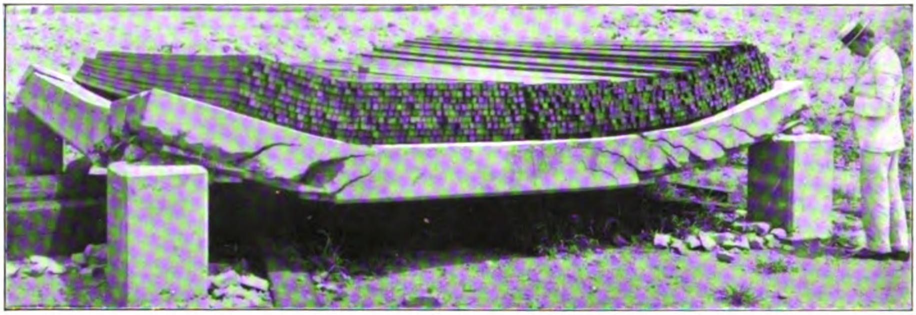

FIG. 2. TEST OF UNIFORMLY LOADED SLAB. FAILURE BY SHEAR.

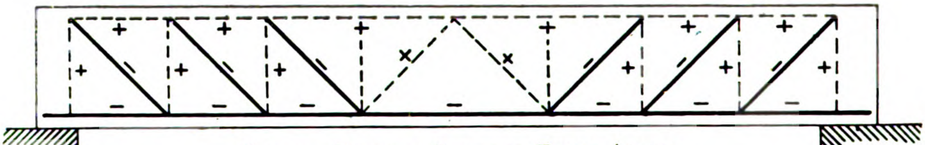

FIG. 3 DIAGRAM SHOWING TRUSS ACTION.

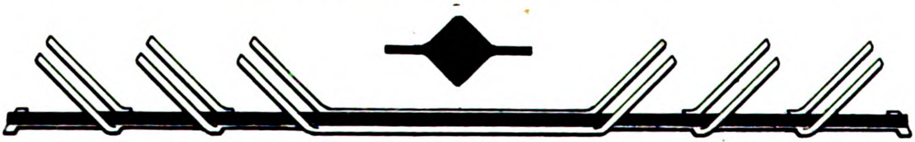

FIG. 4. CROSS SECTION AND VIEW OF KAHN TRUSSED BAR.

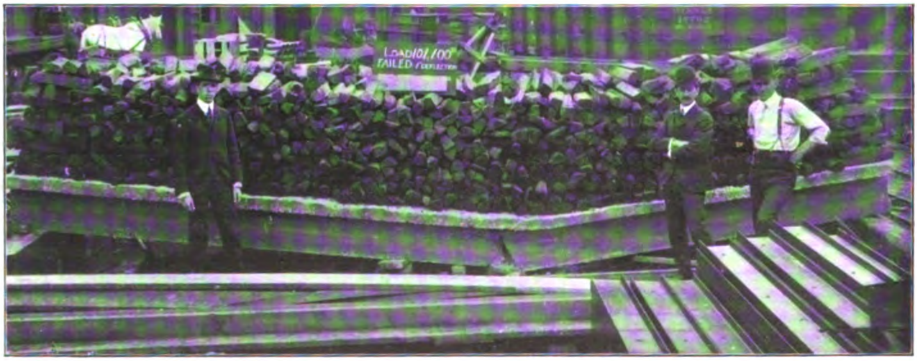

FIG. 5. TEST OF UNIFORMLY LOADED BEAM REINFORCED WITH KAHN TRUSSED BARS.
(Compare with Fig. 2.

that of a truss, in which the tension members consist of steel and the compression members of concrete. Fig. 3 is a diagram showing this truss action.

It is claimed by some engineers that the concrete around the horizontal bar will deliver the stress of the stirrups into the bar and also prevent the slipping of the stirrups along it. Unfortunately, this concrete in question is the first to fail and break away, leaving the bars exposed, as will be seen by again referring to Fig. 2. Or, suppose a strong fire were to flake the bottom layer of the concrete off the beam, there would then be no concrete to perform this function. The advantage of transmitting the strain of the stirrup directly into the bar by a rigid connection, without calling upon the surrounding concrete, is, therefore, readily apparent. To bring out the comparative value of the two methods, a very elaborate test has just been conducted at the Conservatoire des Arts, at Metiers, Paris. Two test beams were used; one reinforced with plain rods and loose vertical stirrups, the other with plain rods on which the stirrups were inclined and rigidly attached. The former failed by shear under a uniformly distributed load; and the stirrups, after examination, were all shown to have slipped. The other beam failed exactly at the centre where the steel pulled in two; but it carried a load 25 per cent. in excess of the former. The full results of this test will be published later.

There are many advantages in having a beam fail at the centre by pulling the metal in two, instead of failing at the ends by shearing of the concrete. In calculating the strength of a beam, we assume that under a uniformly distributed load the maximum bending moment occurs at the centre, and that this is where the beam will fail. If then, in actual test to destruction we find it failing at some other point, our original assumption is wrong and all our subsequent calculations can count for nought. This point is of great importance to designing engineers. Again, when a beam fails by shear, we can only stress the steel to its elastic limit, for we complicate results when we go above this. When, however, the beam fails by actually pulling the steel in two, we know that we can figure on straining the steel up to its ultimate strength. We then have a safety factor in one case which is only one-half that of the other.

To sum up, then, the fundamental principles of reinforced concrete seem to be:—

(1) Concrete should be reinforced in the vertical, as well as the horizontal plane.

(2) The reinforcement should be inclined to the horizontal, preferably at an angle of 45 deg.

(3) The metal should be distributed in proportion to the strains existing at any place.

(4) The shear members should be rigidly attached to the horizontal reinforcement.

In the Kahn system, a bar, with two projecting wings, is used. By a single operation, these wings are sheared, and bent up to form stirrups rigidly connected to the main tension rods. (See Fig. 4.) The stirrups, being bent up at about 45 deg., cross the planes of rupture at nearly right angles. It must be noted that at the centre of the span, where the horizontal tension is greatest, the web is left intact on the bar and there serves as an additional reinforcement. A photograph of a test made, wherein the reinforcement consisted of Kahn trussed bars, is shown in Fig. 5. Here the failure occurred exactly at the centre by severing the steel. There was no sign of a shear crack near the supports. It will be interesting to compare this manner of failure with that shown in Fig. 2.

A form of reinforcement could be used wherein holes are punched in the main tension bar and shear members rigidly connected in these holes. This method, though incorporated in the patents covering the bar described above, is somewhat costly, for not only is the punching and attaching of the stirrups expensive, but the main bar is also weakened by the lost section of the hole.

PRESS SUMMARY.

ARTICLES AND PAPERS

AT HOME AND ABROAD.

The following articles and papers are among the most important published at home and abroad during the last quarter of 1905:—

I.—CONCRETE CONSTRUCTION.

Articles.

Dover Harbour Works. — *Eng. Rev.* Oct., '05.
An illustrated description of the concrete and other constructional works involved in the development of the Commercial Harbour and the creation of the great National Harbour at Dover. By W. Noble Twelvetrees, M.I.Mech.E.

The Sea Wall and Works for Raising the City of Galveston, U.S.A. — *Builder.* 14.10.05
Being a description of the concrete sea wall, 4½ miles long, and other works for the protection of Galveston.

New Graving Dock at Southampton. — *Engineer.* 20.10.05.
This article describes and illustrates the dock built at Southampton by the London and South-Western Railway Company, the largest work of its kind in the world.

A Concrete Building in Liverpool. — *Eng. Rec.* 28.10.05.
The chief merit of the design here described is the facility offered for the utilisation of concrete made with refuse-destructor clinker.

The Use of Concrete in Sewer Construction. — *Deut. Bauzt.* 8 & 22.11.05.

The Niagara Power Plant of the Electric Development Company of Ontario. — *Eng. News.* 9.11.05.
Describing concrete gathering dam constructed.

German Specification for Designing, Constructing, and Testing Concrete Structures. By Leon S. Moisseiff, A.Mm.Soc.C.E. — *Eng. News.* 9.11.05.

Unusual Foundations at the Hoboken Terminal, Lackawanna R.R. — *Eng. Rec.* 11.11.05.
With illustrations showing the concrete footings and retaining walls.

Concrete Block Construction and Architects. — *Eng. News.* 23.11.05.
Dealing with the intrinsic merits of hollow concrete blocks.

The Manufacture of Concrete Blocks and Their Use in Building Construction. — *Eng. News.* 23.11.05.
Being extracts from papers submitted in the *Engineering News* competition.

The Roosevelt Irrigation Dam in Arizona. — *Scient. Am.* 16.12.05.
Illustrating concrete work on a large scale.

Concrete Construction for the B. T. Babbitt Works. — *Eng. Rec.* 30.12.05.
Illustrated description of a large factory near Jersey City, comprising fourteen buildings on pile foundations with concrete substructure, brick and steel superstructure, and reinforced concrete floors.

Concrete Specification for the Kalamath Project U.S. Reclamation Service. — *Cement and Eng. News.* Dec. '05.
Giving details of concrete work for canal construction in S. Oregon.

Papers.

Concrete Building Construction, Including Platforms. By C. W. Richey. — *Assoc. Rly. Supts. of Bridges and Buildings. Pittsburg.* (*Rept. Eng. News.*)
General discussion of the design of concrete buildings for railways. For small buildings hollow concrete blocks and concrete steel roofs are recommended, and for larger buildings either plain concrete or reinforced concrete.

Improved System of Concrete Piling. — *Franklin Inst.* Dec. '05.
Report of the Committee on Science and the Arts on the piling system of Mr. Frank Shuman.

II.—REINFORCED CONCRETE CONSTRUCTION.

(*See also Bridges.*)

Articles.

Tests of an Infirmary Building in Reinforced Concrete. — *Béton Armé.* Oct., '05.
The building is an infirmary and isolation pavilion at the School of the Legion of Honour at Ecouen. The results of tests on the floors and staircases are given.

Reinforced Concrete Construction in the Church of the Cross at Dresden. By Prof. Th. Böhm. — *Deut Bauzt.* 23.9.05.
The roof of the church having been destroyed by fire, has been replaced by a vaulted roof in reinforced concrete, which owing to its complicated form offers several points of exceptional interest.

The Missouri River Power House of the Metropolitan Street Railway Company, Kansas City. By F. G. Cudworth. — *Eng. News.* 19.10.05. 19.10.05.
This building is a steel structure, with hard pressed brick exterior walls, the floors and coal pockets being of reinforced concrete. An extension wall on the east is of plain concrete, and constitutes one of the longest and heaviest pieces of monolithic construction ever built with reinforcement or provision for expansion.

Strengthening of Foundation of the Alexander Church at Zweibrucken (Pfalz). — *Deut. Bauzt.* 25.10.05.
An illustrated account of the strengthening of the foundations of a church, and replacement of wood piling by reinforced concrete.

Water-Tower in Reinforced Concrete. By M Vais, Karlsruhe. — *Deut. Bauzt.* 25.10.05.

Stresses in Chimneys of Circular Section. Dr. R. Saliger, Cassel. — *Beton u. Eisen.* Nov., '05.
Conclusion of a paper on the calculation of stresses in reinforced concrete chimneys. With curves.

Reinforced Concrete Gasholder for the Municipal Gas and Water Works, Wernigerode. By Justus Krüger. — *Beton u. Eisen.* Nov. '05.
The gasholder is 22 metres in diameter, and rests on a loose foundation. Diagrams and a comparison of the cost with that of ordinary concrete construction are given.

Reinforced Concrete Construction—*Continued.*

Gothic Vaultings in Reinforced Concrete. By W. Luder. *Beton u. Eisen.* *Nov.*, '05.

Description of a church with vaulted roofs constructed in reinforced concrete at Bois-le-Duc, near Houdeng (Belgium). Photographs and detail drawings are given. This forms of construction was adopted owing to the liability of the district to subsidences due to the coal-mines.

Protection of Reinforced Concrete Buildings from Lightning. By Dr. D. van Gulik. *Beton u. Eisen.* *Nov.*, '05.

The reinforcement itself provides efficient protection against lightning, if care be taken to connect all metallic parts together and to the earth.

Tests of Reinforced Concrete Beams by the St. Paul Road. *Eng. Rec.* 11.11.05.

Result of investigations carried out by the Bridges and Buildings Department of the Chicago, Milwaukee, and St. Paul Railway, with diagram of reinforced beams, and table giving results of tests.

Corrugated Concrete Foundation Piles. *Eng. Rec.* 11.11.05.

Describing piles used in the construction of a six-story building in Brooklyn.

Concrete Floors without Ballast for Bridges and Roadway. (With diagrams prepared by J. W. Schaub, M.Am.Soc.C.E., Chicago. *Rly. Gazette* 17.11.05.

Calculation of Reinforced Concrete Beams according to the Ministerial Regulations of 16th April, 1904. By Dr. P. Weiske, Cassel: *Zement u Beton* 15.11.05.

Reinforced Concrete Building for the Park Square Motor Mart, Boston. By G. H. Brazer. *Eng. Rec.* 18.11.05.

Describing and illustrating a three-story garage covering an area of about 47,400 square feet.

Silos in Reinforced Concrete. By H. Schürch. *Deut. Bauzt.* 22.11.05.

An illustrated description of silos constructed in various parts of Germany.

Kinzie Street Track Elevation of the Chicago and North Western Railroad. *Rly. Gazette.* 24.11.50.

Description of constructional work with illustrations of the works, and of concrete mixing plant.

The New Coaling Station at Narragansett Bay. *Eng. Rec.* 25.11.05.

A very complete and well-illustrated article giving useful details relating to the concrete-steel, concrete-block, and fire-resisting construction in this extensive range of buildings and wharves.

A Reinforced Concrete Garage in New York. *Eng. Rec.* 25.11.05.

A building with three stories and basement, the concrete-steel main girders having the clear span of 45 ft. (Illustrated.)

Reinforced Concrete in Agricultural Buildings. A. Szuman, Stettin. *Beton u. Eisen.* *Nov. & Dec.*, 05.

Illustrated description of a large barn with reinforced concrete frame, filled in with cement slabs, and of other agricultural buildings.

The S. Salvi Water Tower at Florence. O. Negri di Montenegro, Bologna. *Beton u. Eisen.* *Dec.*, '05.

The tank is cylindrical, with a capacity of 100 cub. m., the tower is hexagonal, the total height above ground is 25 m., the whole being constructed in reinforced concrete.

Bonded Warehouses at Patras (Greece). *Béton Armé.* *Dec.*, '05.

Report of tests on warehouses constructed with reinforced concrete foundation, columns, and floors, and brick exterior walls.

Protecting Gallery of the Mythenstein Tunnel. C. Probst, Lucerne. *Beton u. Eisen.* *Dec.*, '05

The iron gallery protecting the Gotthard railway at Mythenstein from falls of rock having been deeply corroded by locomotive gases since 1882, has been replaced by a gallery of reinforced concrete beams.

Internal Tensile Stresses across the Section of Cement and Concrete Structural Members. By Arno Schleusner, Charlottenburg. *Beton u. Eisen.* *Dec.*, '05

A mathematical investigation of the stresses occurring.

Steel-Concrete at Southampton. By F. E. Wentworth-Shields, M.Inst. C.E. *Times, Eng. Suppt.* 6.12.05.

Particulars of work executed at Southampton Docks, comprising cold store, engine and boiler house; coaling jetty and quay; and the widening of 1,500 feet length of quays.

The Kingsland Shops of the Lackawana Railroad. *Eng. Rec.* 2.12.05.

An illustrated description of the new locomotive and carriage works which are largely built of concrete and steel frames.

A Reinforced Concrete Culvert. *Eng. Rec.* 2.12.05.

An illustrated account of a skew culvert, 100 ft. long, across a stream in Delaware County.

The Reconstruction of the Poughkeepsie Water Filters. *Eng. Rec.* 2.12.05.

Description of reinforced concrete filter construction.

A Reinforced Concrete Bridge. *Eng. Rec.* 2.12.05.

Being description of a bridge 240 ft. long, recently completed in Wabash.

Reinforced-Concrete Shop of Taylor-Wilson Manufacturing Co. *Eng. Rec.* 16.12.05.

Describes a factory building 160 ft. long by 102 ft. wide.

Reinforced Concrete and Tile Construction in an Atlantic City Hotel. *Eng. Rec.* 23.12.05. 30.12.05

A very complete description of an eight and twelve story "fireproof" building, 128 ft. by 326 ft., built entirely of reinforced concrete and terra-cotta, without any structural steel, brick or timber work. Contains interesting view showing the reinforced concrete skeleton, and others relating to various details (Serial).

Construction of the Benguet Road, Luzon, Philippine Islands. *Eng. Rec.* 23.12.05.

Attention is here drawn to the employment of reinforced concrete retaining walls and arches for road construction in very rough country.

The Sewage Purification Works at Columbus, Ohio. *Eng. Rec.* 30.12.'05.

The tanks and filters at these works will be built entirely of concrete and the main distributor and collectors of reinforced concrete. Illustrated.

Remodelling the St. Nicholas Hotel, St. Louis. *Eng. Rec.* 30.12.'05.

This hotel was formerly a six-storey building, but when four extra storeys were to be built, it was found that the foundations and cast-iron columns would not be of sufficient strength for the additional load weight, to provide for which reinforced concrete was considered to be the most suitable material. This article fully describes and illustrates the work of construction.

Ferro-Concrete Pipes. *Public Works.* *Oct. Dec.*

Showing the advantages obtained by the combination of steel and concrete in pipe construction. Illustrated.

Reinforced Concrete Construction—*Continued.*

Papers.

Reinforced Concrete Applied to Modern Shop Construction.
Am.Soc. Mech.E. Dec., '05.

Pointing out the advantages of concrete-steel in workshops construction, and giving practical data relative to a factory building of this class erected in Pennsylvania. Illustrated.

The Planning and Construction of Factory Buildings with Special Regard to the Application of Armoured Concrete. By H. A. Alban H. Scott, M.S.A.
Inst. San. Eng. 16.12.'05.

After dealing with the lack of uniformity of design and materials of construction in England, the author compares the costs of buildings designed with armoured concrete and those consisting of ordinary construction.

Report on Deterioration of the Roofs of the Quarantine Sheds at Mex.
Rept. State Bldgs. Dept. Public Works Ministry, Egypt.

This forms an appendix to the annual report of Mr. Perry, Director-General of the Towns and State Buildings' Department, and states the reasons that led to the failure of the iron and the concrete in the *beton armé* roofs of this building. The same report also contians illustrations and statistics relative to different systems of fire-resisting flooring recently adopted in Egypt.

Ferro-Concrete Construction. By T. J. Gueritte.
Archl. Assoc., Edinburgh. 13.12.05.

Referring to the claims of reinforced concrete and particularly of the Hennebique system.

Armoured or Reinforced Concrete. By Philip H. Palmer, M.Inst,C.E.
Incorp. Assoc. Municipal & County Eng., Vol. XXXI., 1905.

After dealing with various systems of reinforcement, the author describes examples of reinforced concrete structures in various parts of the world. Illustrated.

Reinforced Concrete Piling. By A. R. Galbraith, A.M.Inst.C.E.
Incorp. Assoc. Municipal & County Eng., Vol. XXXI., 1905.

Dealing with the advantages of reinforced concrete piles, drawing attention to various systems of reinforcement exemplifying the application of reinforced concrete piling. Illustrated.

III.—STEEL CONSTRUCTION.

(*See also Bridges.*)

Articles.

New Shops of the Watson-Stillman.
Eng. Rec. 10.14.05.

Details of the steel framework. With illustrations.

The Steel Shed of Pier No. 7, South Brooklyn.
Eng. Rec. 10.28.05.

Describing a one-story steel structure on the water-front of New York Harbour.

Structural Details in a Maiden Lane Building.
Eng. Rec. 18.11.05.

Describing a steel-cage building erected in New York, and containing about 400 tons of structural steel.

Modified Saw-Tooth Roof as Used in New Paint-Shop of the Public Service Corporation, Newark, N.J. By M. S. Kitchum, A.M.Am.Soc.C.E. Illustrated.
Eng. News. 23.11.05.

Steel Sheet Piling in the Hillsdale Reservoir Dam.
Eng. News. 23.11.05.

With illustrations showing concrete core-wall nearly completed.

Improvements of the New York Central and Hudson River Railroads within the Electrical Zone. By G. R. Wadsworth.
Rly. Gazette. 1.12.05.

Including description of power houses exemplifying steel-frame and concrete construction.

The Lesson of the Charing Cross Accident.
Builder. 23.12.05.

With illustrations giving details of Charing Cross station roof, and discussing various points connected with the failure.

The Charing Cross Disaster.
Engineering. 22.12.05.

Dealing with the cause of the accident, describing the removal of the old roof and the type of the new roof for the station.

Papers.

The Theory of Frameworks with Rectangular Panels, and its Application to Buildings which have to Resist Wind. Illustrated.
Am.Soc.C.E. 1.11.05.

American Methods of Erecting Buildings. By R. A. Denell.
R.I.B.A. 20.11.05.

Comparing English and American practice, and commenting upon the large amount of cast-iron work used in the States in the framework of buildings.

IV.—MATERIALS AND TESTS.

Articles.

The Welding of Iron and Steel by the Oxygen Blowpipe.
Mech.World. 10.11.05

Preservations for Wood and Metal.
Eng. News. 26.10.05.

Strains and Strength of Materials. By C. F. Blake.
Machinery. Nov., '05.

Grayel Concrete
Eng. Rec. 11.11.05.

Some Peculiarities of Cement. By W. A. Aiken.
Assoc. Am. Portland Cement M'rs.

With diagrams and tables.

Influence of Immersion on Dried Cement Mortars containing Gypsum. By J. Gresly, Liesberg (Switzerland).
Ciment. Dec., '05.

The behaviour of briquettes dried at 130°, 200°, or 300° C., after setting, and then immersed in water, has been studied with a view to determining the influence of gypsum on the properties of the mortar.

La Prise et le Durcissement des Ciments.
La Revue Techn. 10.12.'05.

A thoughtful discussion on the setting of Portland and other cements.

Unprotected Ironwork.
Times Eng. Suppt. 20.12.'05.

Pointing out the economy and general superiority of reinforced concrete as a substitute for painted steel in structural work.

The German Cement Industry.
Times Eng. Suppt. 20.12.'05.

This article is based upon a report furnished by the Consul-General at Hamburg upon the cement industry, and contains information of particular interest at the present time.

Suggestions on the Use of Hollow Concrete Building Blocks. Illustrated.
Cement and Eng. News. Dec., '05.

A Modern Puzzuolana Cement Works.
Cement and Eng. News. Dec., '05.

Description of the plant and process of cement manufacture at the works of the Ashland Iron and Mining Co., Kentucky.

Materials and Tests—*Continued.*

Papers.

Metallic Preservation and Ornamentation of Iron and Steel Surface. By Sherard Cowper-Coles. Describing the dry galvanising and other preservative processes discovered by the author.	*Soc. Eng.* 6.11.05.
The Elastic Properties of Steel at High Temperatures. By Prof. Hopkinson and Mr. F. Rogers. Illustrated.	*Royal Soc.* *(Rpt. Eng.* 18.11 05.
The Behaviour of Materials of Construction under Pure Shear. By E. G. Izod, A.M.Inst.Mech.E. Giving details of experiments at University College to test the effects of shear on several materials of construction. Containing tables and diagrams of results.	*Inst. Mech. E.* 15.12.'05.
Experiments for Determining the Elastic and Ultimate Strength of Brickwork Piers and Pillars of Portland Cement Concrete. By William Charles Popplewell, M.Sc., A.M.Inst.C.E. This paper deals with tests at the School of Technology in Manchester, upon samples of brick, concrete, and reinforced concrete.	*Inst.C.E.* *Vol. CLXI.* '05.
Portland Cement. By H. K. G. Bamber, F.C.S. The author deals in an instructive manner with correct methods for testing cement and with modern cement manufacture, also drawing attention to the advantages obtained by the use of Portland cement concrete reinforced with iron or steel.	*Incorp. Assoc. Municipal and County Eng. Vol. XXXI.*, '50

V.—CONTRACTORS' PLANT AND PRACTICE.

Articles.

A Push Cart for Transporting Concrete. Illustrated.	*Eng. News.* 5.10.05.
Notes on Workmanship in Riveting. By A. J. Himes, M.Am.Soc.C.E.	*Eng. News.* 29.10.05.
The Mechanical Handling of Materials.	*Builder.* 28.10.05.
Transferring a 2,000-ton Wall to Columns and Girders	*Eng. Rec.* 4.11.05.
Sinking a Foundation Caisson with Post Hole Augers. Illustrated.	*Eng. Rec.* 18.11.05.
Waterproofing Brick Arches.	*Eng. Rec.* 25.11.05.
Manufacture of Broad Flange Steel Beams. A descriptive article with illustrations showing the various stages and processes of manufacture.	*Canadian Eng.* *Dec.*, '05.

Papers.

Concrete Mixers, By J. S. Owens, A.M.Inst.C.E. This paper deals with processes involved in the production of concrete, and describes various types of concrete-mixing machines.	*Civ. & Mech. E. Soc.* 7.12.05

VI.—SPECIAL SUBJECTS (BRIDGES).

Articles.

A Reinforced Concrete Bridge, Sorsogon, Philippine Islands, by H. L. Stevens, Prov. Supervisor.	*Eng. Rec.* 21.10.05.
Railway Bridge in Reinforced Concrete at Viviez, Aveyron. With a report of tests under dead and live load.	*Le Béton Armé.* *Nov.*, '05.
Parabolic Concrete Arch Bridge, Washington, D.C. Dealing with the general design and construction of an unusual type of bridge, having an arch ring with the clear span of 125 feet. Illustrated.	*Eng. News.* 16.11.05.
The Real Influence of Moving Loads on Bridge Structures.	*Eng. Rec.* 18.12.05.
The Design of the Post Base of the Manhattan Bridge Towers. Description of the constructional work. (Illustrated with sectional drawings.)	*Eng. Rec.* 25.11.05.
The Reinforced Concrete Bridge at Lake Milwaukee. With illustrations of the work in course of erection and completed.	*Eng. Rec.* 25.11.05.
The Calculation of Reinforced Concrete Columns and Recent Experiments. By Prof. Mörsch, Zürich. The bearing of Bach's experiments (see above) on the calculation of the strength of reinforced concrete columns is discussed, and certain modifications of the accepted rules are suggested.	*Deut Bau t.* 4.10.05.
Aqueduct in Reinforced Concrete. By L. Bravet. The aqueduct, partly in the form of an open canal 6 m. in width, partly in that of a cylindrical conduit 3·3 m. in diameter, conveys water from the Romanche (Isère) to the turbines of a factory at Clavaux, and is constructed throughout in reinforced concrete. Illustrated.	*Béton Armé.* *Dec.*, '05.
Concrete Bridge over the Lenne. With illustrations, including diagram giving details of hinge.	*Engineer.* 1.12.05.
Reinforced Concrete Bridge at San-Sebastian, Spain,	*Zement u. Beton.* 1.12.05.
Displacement of the Semi-Arches of a Stone Bridge. This is an illustrated article discussing the accident to the recently erected Maximilian Bridge, at Munich, over the Isar.	*Engineer.* 29.12.'05.

Papers.

Ferry Bridge Across the Ship Canal at Duluth, Minnesota, by C. A. P. Turner, M.Am.Soc.C.E. This paper deals with a novel form of "transporter" bridge, recently erected for the conveyance of street traffic across the ship canal between the city of Duluth and Minnesota Point, Lake Superior. The span is 393 ft. 9 in. from end to end. The details in this paper are of considerable interest, especially those relating to the method of bringing the travelling carriage to a standstill at each end of the bridge. (Illustrated.)	*Am. Soc. C.E* 15.11.05

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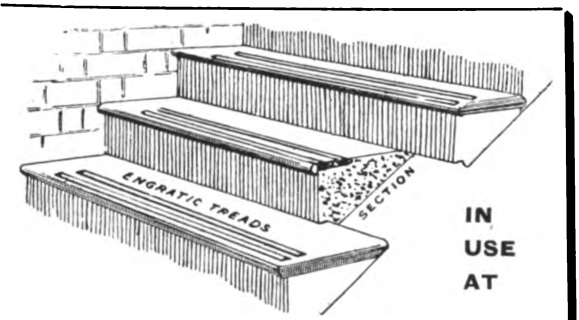

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CONCRETE
AND
CONSTRUCTIONAL ENGINEERING

Volume I. No. 2. MAY, 1906.

EDITORIAL NOTES.

THE reception of this journal has quite surpassed our most sanguine expectations, and to all those who have so courteously congratulated us upon our first number, we would express our heartfelt thanks. In particular we would express our high appreciation of the flattering comments of our technical contemporaries. We trust that the execution of our programme of presenting reliable technical and economic information on the subject with which we are primarily associated will be fulfilled in a manner thoroughly satisfactory to the professions and industries concerned, and that the independent position we have taken up will continue to meet with approval and support. We must necessarily at times express views which may not be as orthodox or as insular as is generally expected by those accustomed to well-trodden paths, but we would immediately state that the theme only—never the personal element—interests us, and our sole object is to advance a subject that has been much neglected in Great Britain, owing probably mainly to the natural conservatism of our engineers and architects.

Concrete is destined to play an all-important part in our great structural works, whilst steel-frame construction must necessarily also make considerable progress during the next few years. A proper understanding of advantages and disadvantages, of economic and theoretical factors, and, further, of safeguards to be observed, must materially assist the development of modern constructional engineering. To assist in obtaining this understanding among the professions and industries affected by giving independent publicity to reliable information is a means for obtaining the advancement desired.

THE ROYAL INSTITUTE OF BRITISH ARCHITECTS AND REINFORCED CONCRETE.

In our first issue we referred to the arrangements made by the Royal Institute of British Architects for dealing with reinforced concrete, and the Special Committee entrusted with the subject under the able chairmanship of Sir Henry Tanner, has now commenced work. Whilst the District Surveyors' Association and the Association of Municipal and County Engineers are represented on the Committee, we, however, observe that neither the Institution of Civil Engineers or the Institution of Mechanical Engineers have apparently so far accepted the invitation to appoint delegates. Seeing that the subject is so very much an engineering one, this is regretable, for it naturally now follows that the work undertaken by the Royal Institute cannot be truly representative of the great technical interests concerned. Eventually some further joint conference must be undertaken in conjunction with the leading engineering societies, or the whole matter will have to be referred to the Engineering Standards Committee, with the addition of some representation from the Royal Institute. Nevertheless, the work of the Institute cannot but be useful, and may throw additional light upon the subject, beyond that revealed by the investigations of the United States and the Continent of Europe. The credit of inaugurating the first independent inquiry on reinforced concrete, as far as Great Britain is concerned, also remains with the Institute.

As to the Committee's programme of work or primary objects, no official announcement has been made, and thus various incorrect views as to their intentions are being given publicity. It might not be inexpedient for the Committee to issue a programme of its work and investigations.

In making arrangements for any tests, we would, by the by, suggest that all investigations undertaken by the Institute, or under its auspices, should be conducted either at public laboratories or on the premises of some educational body or technical society, and not at the establishment of any individual firm, however eminent. The subject under inquiry is, unfortunately, at present already so much under the influence of individual vested interests, that this question of location is of importance.

AN IMPORTANT GOVERNMENT INQUIRY ON CONCRETE IN THE UNITED STATES.

Under the heading "Research Work," we shall occasionally call attention to various inquiries which are being conducted in different parts of the world, and we would take this opportunity of congratulating our American cousins on the extraordinarily able manner in which one of these inquiries is now being conducted on the various questions appertaining to the use of cement and concrete. The constitution of an official United States Advisory Board on these matters is a move which we could well imitate, not only in matters relating to the subject we have specially at heart, but in many other departments of research work. We are presenting particulars as to the programme of work prepared by the Board.

FICTITIOUS PORTLAND CEMENT.

In our first number we mentioned at some length the all-important question of fictitious Portland cement. Our comments arose from a pamphlet that had been published, entitled "A Modern Danger," which pointed out the great risks that are being run by the use of natural cement where Portland cement, *i.e.*, the artificial product, should be employed. Numerous comments have reached us, one and all endorsing our views, and we are publishing two of the many letters we have received. One of these calls attention to the very serious aspect of fictitious cement in the development of reinforced concrete, and the other speaks of a German warning against the use of Belgian natural cement, and how the Germans deal with fraudulent descriptions.

We have also had our attention called to numerous cases where both the architects or engineers in charge, and the contractors, whose *bona fides* were indisputable, have been trapped into using fictitious Portland cement. In some cases well-known makers' sacks, the contents of which for early deliveries were quite genuine, have been got hold of by builders' merchants, and filled with the unreliable natural product. In other cases foreign natural cement has been sold boldly under a fictitious label as "Portland," *i.e.*, as the artificial product.

We have already expressed our views as to a remedy, namely, that in the first place, the Merchandise Marks Act requires a different reading so that it should not encourage—as it does at present—the import of materials under fraudulent descriptions. Further, we hold that there should be some Act, equivalent to the Food and Drugs Act, which will make it an offence easily ascertainable and punishable, to sell under false presences a building material that does not fulfil its description. We now hear that Sir Howard Vincent has again brought in a Bill which should at least do something towards preventing the sale of fictitious foreign natural cement in place of the artificial home product, and also give foreign artificial products a label of origin. If but one of these remedies were adopted, a stop would soon be put to what must be a public danger.

SIR HOWARD VINCENT'S BILL AS TO THE ORIGIN OF MATERIALS.

As to Sir Howard Vincent's Bill, the proposal is that all goods of foreign manufacture, which by reason of any mark, name, or description, or words appearing thereon, may be fraudulently sold as being of British or Irish manufacture or production, shall be henceforth prohibited to be imported into the United Kingdom, unless such goods bear in some conspicuous place the word "Foreign" or the word "Imported" if made in a foreign country, or the word "Colonial" if made in a British Colony or possession oversea.

Certainly this would be a most valuable step in the right direction, for we consider that the truthful labelling of commodities is a primary necessity to honest business and sound construction.

It would be difficult to find any argument against Sir Howard Vincent's reasoning, and it might as well be known that in America, in France, and we believe also in Germany, the law requires all goods imported to have the word "Imported" conspicuously marked thereon, or the equivalent thereto.

Further, as far back as the Industrial Conference of Rome, some international legislation of this description has been recommended, and besides this the Select Committee of the House Committee of 1897, quite distinctly advised the stamping of all imported goods with the words "Made Abroad."

Sir Howard Vincent, we believe, has made several efforts to obtain a hearing for the Bill, and it is to be hoped that he will be successful with what would be a most useful safeguard against a growing danger.

REASONABLE RESTRICTIONS AGAINST BAD CONCRETE.

As believers and advocates of concrete as a fire resistant, this journal fully realises the necessity of suitable control being exercised, so that only sound work be obtained Accidents would bring concrete into discredit. But whilst advocating suitable and fair precautionary measures, this journal will have the interests of the employer, his adviser and the contractor at heart, and certainly point to, and if necessary energetically oppose, anything that may unduly restrict its development.

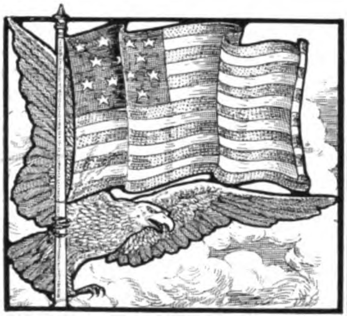
In one direction, however, we think that special care should be taken in impending restrictions, and that is that those in authority should clearly define the nature of the cement permissible in concrete intended to be fire-resisting, as also in reinforced concrete generally. Portland cement alone should be allowed, and as far as British work is concerned, only British Portland cement conforming to the 1904 standard should preferably be employed.

Given restrictions as to the use of aggregate and the employment of reliable British Portland cement, and further reasonable limitations as to the protection of any steel used, the public authorities should be able to obtain concrete construction that is fully fire-resisting, and should be a valuable adjunct in limiting the conflagration hazard of the large cities.

Given the suitable protection, and given the suitable aggregate, it would indeed be difficult to find a form of construction more suited to afford fire protection in buildings than reinforced concrete, but that proviso is an essential which some of the pioneers—both at home and abroad—in their enthusiasm have overlooked.

THE DETERIORATION OF REINFORCED CONCRETE ROOFS IN EGYPT.

In the last report of the Public Works Department of Egypt, there is an interesting note by Mr. Ehrlich relative to the unsatisfactory behaviour of reinforced concrete in the roofs of the cattle quarantine sheds at Mex. These buildings were open sheds built entirely of reinforced concrete at a distance of about 65 ft. from the sea, and in a place where they were exceptionally exposed to climatic extremes. Therefore it was essential that the utmost care should have been taken with regard to the composition and proportions of the concrete work. From the report made by a special commission appointed to inquire into the failure, it is, however, clear that these conditions were not complied with. The concrete was neither air-tight nor water-tight, and soon after the commission had met it was established in very conclusive manner that the employment of local non-silicious limestone had played a chief part in the destruction of the roofs. Mr. Ehrlich says that the predominance of this material in the concrete had the effect of adulterating and replacing in part the cement which was the chief guarantee of impermeability. Thus it is shown that the deterioration of the roofs was due to neglect of obvious precautions, and in no way reflects upon the reliability of properly-proportioned and well-mixed concrete as a durable material and an efficient protection for the iron employed as reinforcement. The moral of this failure is that in addition to the necessity for correct design in reinforced concrete construction, all the materials for the preparation of the concrete must be carefully selected and mixed in proper proportions and in approved manner, and that the subsequent deposition of the concrete must be performed under thoroughly competent superintendence. Neglect of such precautions will surely lead to unreliable work, and so tend to prejudice the new material in the eyes of engineers and the public.



REINFORCED CONCRETE IN THE UNITED STATES.

By Captain SEWELL,

Corps of Engineers, United States Army.

This article is intended to review the development of reinforced concrete in the United States as far as buildings are concerned, and to supplement the general article on the "Advent of the Concrete Age" presented in the preceding number. As in the general article by Lieut-Colonel WINN, the author of the present article is a military engineer of recognised authority and independence, whose plain speaking on the fire resistance of concrete on the occasion of the Baltimore conflagration, will be remembered by many. It will, however, be observed, that questions of safequards against fire, as also those relating to calculations and tests, etc., are not at present dealt with by the distinguished author. An article by Captain SEWELL, specially arguing both the theoretical aspect and that of fire resistance, is, however, in preparation for publication in an early issue of this Journal.—ED.

EARLIER HISTORY.

THE principal development of reinforced concrete construction in the United States has occurred since 1890; indeed, most of it since 1895. It undoubtedly received a great impetus about 1889-1890, because of the introduction of the rotary cement kiln, and the consequent great cheapening of Portland cement. The new form of construction did not really attain a lusty rate of growth, however, until after 1895; at the present time it is not only growing, but at an amazingly increasing rate, and that, notwithstanding it is still regarded by many as in the experimental stage.

But, at a date much earlier than those above mentioned, reinforced concrete had attracted the attention of inventive Americans. The experiments of Thaddeus Hyatt, published in 1877, together with his very lucid reasoning on the subject are no doubt, well known in England, since the experiments were made, and the results published, in London. Further, a certain W. E. Ward is credited with having built a house in the United States, as early as 1875, in which the columns and floor systems were of reinforced concrete. But probably the man who did more than any other to introduce this form of construction is Mr. E. L. Ransome, who, I believe, put up his first building in 1884, and has since that time successfully completed many buildings, in some of which he solved structural problems of no mean order.

In more recent years, a multitude of patented systems have been developed, most of them serving simply as an excuse for going into the reinforced concrete business, and very few of them presenting evidence of scientific thought or design.

TYPES OF REINFORCEMENT FOR BEAMS AND GIRDERS.

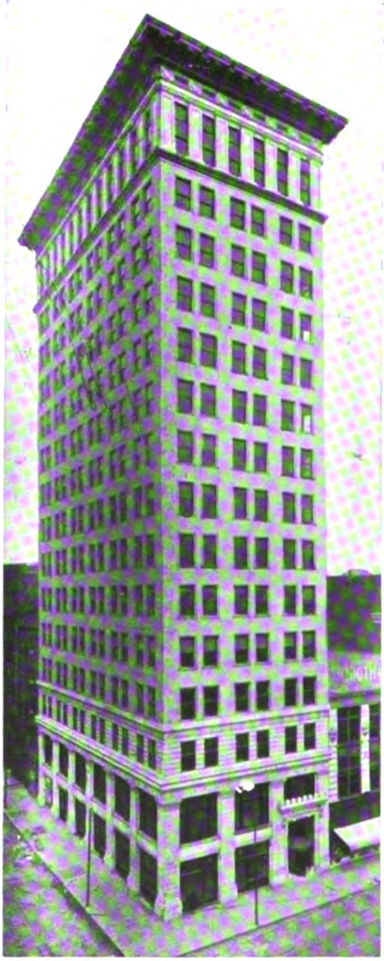
One of these systems, however, is worthy of mention ; it is the Hennebique, introduced from France, to the best of the writer's knowledge, about the end of the nineties. The peculiar feature of the Hennebique system, which originally made its introduction into the United States a matter worthy of special notice, is the definite and intelligent provision against failure under web stresses, in reinforced concrete beams. The writer has seen designs by E. L. Ransome, made in 1891, in which vertical, U-shaped stirrups were used, passing under the main bars, near the ends of the span, in much the same way as in the Hennebique designs. But Ransome did not always use them, and it was undoubtedly the introduction of the French design referred to which really brought home to American engineers the vital necessity for reinforcing against tensile web stresses.

Since then, two very important advances have been made in the United States ; one of them is the attachment of the web reinforcement to the horizontal reinforcement, so that they are firmly fastened together, without any assistance from the concrete ; the other is the plan of arranging the tensile web members at an angle of forty-five degrees, so as to parallel the tensile web stresses. While both of these principles seem to be clearly enough indicated in previous designs, both American and European, their importance would not have been so clearly recognised as it is now, but for their development by Julius Kahn, of Detroit, about three or four years ago, and their subsequent commercial exploitation.

In the writer's judgment one more step remains to complete the theory of reinforcing concrete against transverse rupture, and that is, to vary the spacing or the cross section of attached web members according to the value of the tensile web stress, at every point. So far as he is aware, some work designed and executed by himself at the Army War College, Washington Barracks, D.C., is the only existing example of rigidly attached web members used in this way. Hennebique, and all subsequent designers using free or loosely attached stirrups for web reinforcement, have generally diminished the spacing, or have increased the section of individual stirrups, near the ends of the span. But nothing of the sort has previously been done with attached stirrups. The War College work in question was designed in July and August, 1904, and *Figs.* 1, 1a, and 2 presented herewith show some typical girders and the method adopted for reinforcing them. The main bars consisted of rectangular sections, set on edge. Holes were drilled from the solid, along the axis of the bar, of proper size to receive the round bars designed for use as web members ; these were cut to twice the length of a web member, plus the thickness of the main bar ; they were then heated in the middle, thrust through the main bar as far as the middle point of the web member, bent up at a proper angle, and the heated part hammered down, so as to upset and completely fill the hole, as a rivet would have done. The complete reinforcement was thus built up, and then set in position as a whole. The connections of the web members were quite rigid. The labour cost of assembling was about five dollars (£1) per ton of 2,000 lb. This was a rather clumsy and expensive method of obtaining the desired result, but it was the best the writer could devise in the time at his disposal. As soon as the principles involved have received more general acceptance, neater and less expensive methods will no doubt be devised.

FLOOR SLABS.

What has been said so far, relates more to the types of reinforcement for girders and beams than for other members of a structure. Floor slabs, in the beginning, were almost the only form in which reinforced concrete was applied. At first, they were reinforced with plain or deformed longitudinal bars, or with a metallic mesh, such as wire fabric, or expanded metal. For slabs of moderate span and thickness, this is still the general practice in the United States, although all slabs executed under the Kahn system, and a portion of those executed under other systems, have web reinforcement to a greater or less extent. A combination of hollow tiles and reinforced concrete joists is coming to be used instead of slabs, in many cases—especially where a moderate increase in thickness as compared with a slab of the ordinary type is allowable. In *Figs.* 3 and 3a, sections of such a floor, as applied at the War College, are shown. In the writer's judgment, when lightness and strength are considered, this form of floor gives a greater return for its cost than any other now available.



* REINFORCED CONCRETE OFFICE BUILDING, CINCINNATI, U.S.A.
(Sixteen floors, 100 ft. by 50 ft., 210 ft. high.)

COLUMNS.

Reinforced concrete columns in the United States have been built with all sorts of longitudinal reinforcing bars, both with and without lateral ties. Hooped columns have been used to some extent in the United States, and also in Canada. The general tendency is now undoubtedly towards the use of the hooped column, with longitudinal reinforcement inside of the hooping, not only for resisting flexure, but also for resisting compression, where a column of moderate dimensions must be made to carry a very heavy load.

WALLS.

Where entire buildings are constructed in reinforced concrete, the tendency is towards a type in which a complete framework is enclosed by relatively thin and light—sometimes hollow—curtain walls, carried, story by story, on the framework proper.

OTHER USES OF REINFORCED CONCRETE.

With the possibility of designing and building efficient columns, girders, beams, floor slabs, and walls, of any structural material, once established, all limitations

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* No special system of reinforced concrete used.

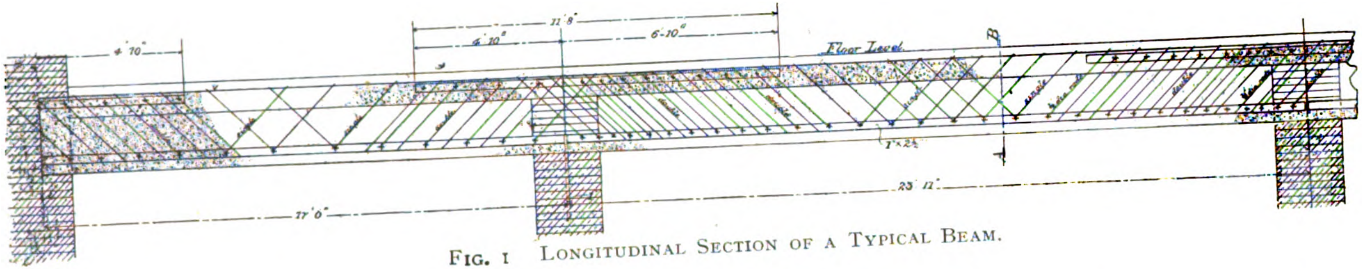

FIG. 1 LONGITUDINAL SECTION OF A TYPICAL BEAM.

142

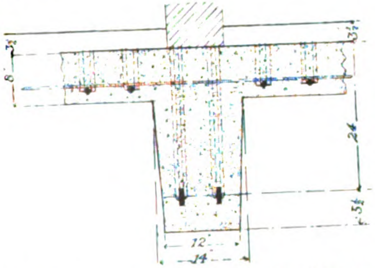

FIG. 2. SECTION OF A MAIN BEAM.

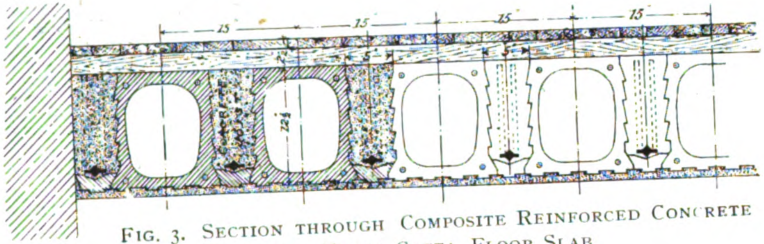

FIG. 3. SECTION THROUGH COMPOSITE REINFORCED CONCRETE AND TERRA COTTA FLOOR SLAB.

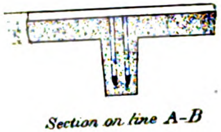

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FIG. 1A. CROSS SECTION OF A TYPICAL BEAM.

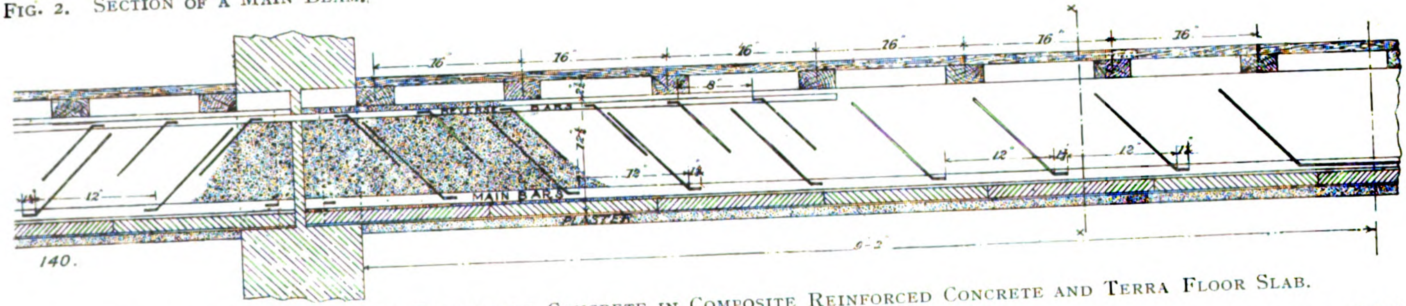

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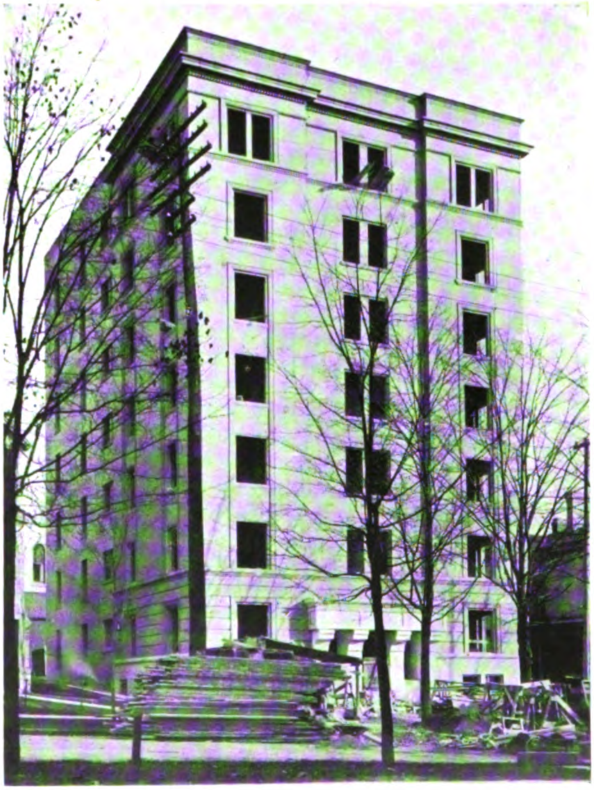
FIG. 3a. SECTION THROUGH REINFORCED CONCRETE IN COMPOSITE REINFORCED CONCRETE AND TERRA FLOOR SLAB.

DETAILS OF REINFORCED CONCRETE BEAMS AND FLOOR SLABS AT THE ARMY WAR COLLEGE BUILDING, WASHINGTON BARRACKS,, U.S.A.

as to its possible uses disappear. So, reinforced concrete is now applied in the form of thin footings for foundation work; in the form of hollow cribs for pier work; hollow dams, high chimneys, sewers, culverts and bridges, coal and grain bins, in fact, every sort of structure is now executed to a greater or less extent in the new material; so that—as my British colleague, Lieut.-Colonel Winn, so ably argued in the preceding issue of this journal—this century is truly likely to be known as the Concrete Age.

OPPOSITION AND OBSTACLES.

Conservatism and established interests have not failed to resist the increase in the use of reinforced concrete in the United States, as elsewhere. The conservative engineer very properly declines to commit himself to a new form of construction until it is well tried out. Commercial men interested in the prevailing modes naturally resist anything new which really or apparently threatens their interests. Building control departments are not always presided over by men of great ability or of sound technical training. Architects have been loth to look into new forms of construction not directly affecting the artistic side of their work—the part in which they are supposed to be most interested. Owners are not willing to adopt anything which will not pass the municipal building departments without a struggle. Considering the state of the knowledge of the properties of concrete and steel as it was ten or fifteen years ago, it is not strange that engineers looked with suspicion upon a composite material, made of such diverse materials as steel and concrete. Whether they would really act as one; whether, if they did, their union would be permanent; the effect of possible differences in the rates of expansion and contraction; the effect of initial strains due to changes



* Reinforced Concrete Tenement Building, Battle Creek, Michigan, U.S.A.

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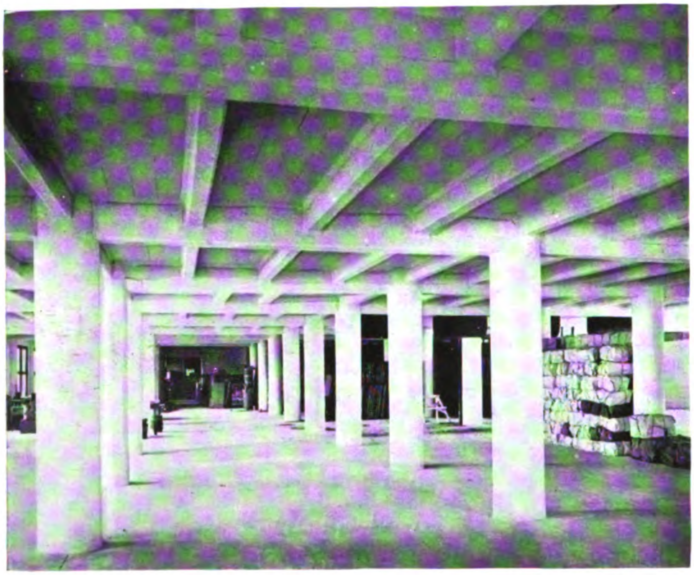
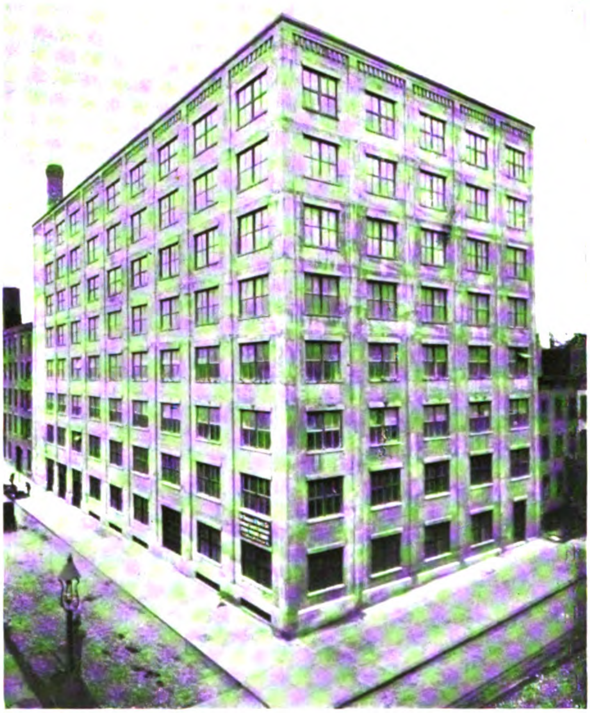
* "Kahn" system of reinforced concrete.

of volume of the concrete in setting; the possibility of the corrosion of the steel—all these were serious questions. Indeed, it seems doubtful whether, if it had been left to men with too intimate a knowledge of the properties of materials, such a combination as reinforced concrete would ever have been developed. In this case, as in many others, a bold and inventive mind, untrammelled with too much theoretical knowledge, was a necessary qualification in the pioneer. Gradually, and in the face of much persistent opposition, the new material has forced its way into public favour and official recognition. At first, it was adopted only in places where building laws were unknown; finally, municipalities began to admit it in buildings not required to be "fireproof," subject to rather severe loading tests; then, in fire-resisting buildings, subject to limitations and safeguards. At the present time, most of the large American cities have regulations governing the use of reinforced concrete; the National Board of Fire Underwriters have also issued a model building law, containing such regulations. The extracts from the New York law, quoted in the excellent little English work by W. Noble Twelvetrees, are a fair sample of all, except that the "model law" of the National Board of Fire Underwriters is rather broader and more liberal than the others, and, in the writer's judgment, rather safer. The New York law seems to be a compound of Christophe's analytical treatment and of Hennebique's empiricism, modified as to constants by the results of laboratory tests in the United States.



Reinforced Concrete Factory Building, Brooklyn, U.S.A.

The attitude of municipal building departments and of structural engineers towards reinforced concrete has not been by any means free of inconsistencies. At first, the owners of any so-called "system" of reinforced concrete, by building a small sample floor, and subjecting it to a rather severe loading test, could have their "system" accepted as such, and plans calling for it were passed, without much scrutiny as to variations in design to meet varying conditions. Contractors with an intelligent understanding of their material, and some sense of honour as to the factor of safety, were naturally at a disadvantage under such circumstances, when in competition with ignorance and recklessness, as they generally were. In some cases known to the writer, the contractor for reinforced concrete construction was required to load an entire unit of the floor system, consisting of the area between four columns, with such a load that the total was equal to six times the sum of the dead weight and the working load. Thanks to that part of the factor of safety which is beyond the power of any one to figure, the floors stood; they were then accepted, and even the tested part was allowed to stand, without reference to the serious injury it had probably sustained in the test. In another case, where the contractor had figured his work according to the formulas of a certain system, and had taken full advantage of the indeterminate margin of safety, the architect required a load equal to four times the total working load; the floor did not fail, although it received a very serious permanent deflection. It was allowed to remain, and was put into service. The same contractor, on another occasion, had a rather serious failure under the test loading, involving loss of life. He allowed the writer to see his working drawings in this case, and it was evident that he had figured the floor to just stand up under the specified test load, and no more. He used bags of sand for a test load; they were filled and weighed dry; just before the failure, they were exposed to a rain, and the water absorbed was no doubt the only thing that prevented another seriously injured floor from going into use, under vibrating machinery in this case.



* REINFORCED CONCRETE FACTORY BUILDING, BROOKLYN, U.S.A.

In another case, a design made according to the formulas of the same system was proposed for a school house, as a substitute for steel beams and flat terra-cotta arches. This time, the formulas were very conservatively used, and the concern proposing to do the work was known to be responsible and careful. The reinforced concrete design had certainly a larger factor of safety than the steel and terra-cotta design; but a consulting engineer—a very skilful structural designer—to whom the matter was referred, refused to approve it, because he could not, by formulas similar to those recommended by M. Christophe, figure a factor of safety of four, based on the elastic limit of the steel, and an ultimate stress of about 2,000 lb. per square inch in the concrete. In the steel and terra-cotta design, based on the elastic limit of the steel, the factor of safety was certainly not more than two.

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* No special system of reinforced concrete.

It appeared to the writer from the beginning of his experience with reinforced concrete, that if the new material had unknown and indeterminate defects necessitating the use of a much larger factor of safety than was customary in steel designs, it was not safe to use at all. In his subsequent experience, with well-executed work designed with the same supposed factor of safety as would have been used in steel construction, he has never been able to make the floors show any signs of failure whatever under their computed breaking loads.

RESULTS ATTAINED AND ECONOMIES EFFECTED.

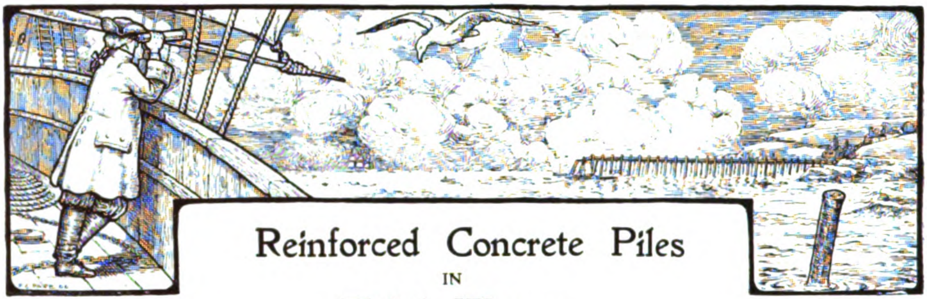
Some of the unreasonable exactions and inconsistent liberality with which reinforced concrete has been treated in the United States have been indicated above. With the diffusion of knowledge concerning it within the last three years, its use has become much more logical and consistent. When compared in cost with a steel-frame building, fairly well " fire-proofed," it appears that the cost of an equivalent reinforced concrete design should be less than that of the " fire-proofed " steel design by an amount varying from thirty to sixty per cent. of the cost of the steel frame, without the " fire-proofing." The concrete is about equivalent in cost to the fireproof beam and column protection and floor arches required with the steel frame, and the steel reinforcement of the concrete should not cost more than forty to seventy per cent. as much as the metal in the frame. However, these economies have not always been realised for several reasons. Where special reinforcing shapes have been used for the concrete, the steel mills, fearing the competition of the new material, have not always been willing to furnish the shapes at a price based solely on the cost of production; the actual work of construction has also been largely in the hands of special concerns, so that the general contractor has had to sublet the reinforced concrete. This often involves the moving of plant and trained men considerable distances for comparatively small pieces of work. As architects, and many engineers, have not studied the subject sufficiently to make their own designs, the various concerns in the reinforced concrete business have been compelled to design every job they figured, while they were sure to lose most of them. For all of these reasons, the construction work has been handicapped by large incidental, contingent, administrative, and advertising expenses, so that the actual saving has often been much less than it apparently ought to be. Where the general builder has been able to handle the work, however, the saving has actually been effected. The contractor furnishing the bars for the War College tile and concrete floors, illustrated in *Fig.* 3, named a tentative figure of 55 cents (say 2s. 3½d.) per square foot for doing the work. The building is being erected by hired labour, under the writer's direction, including the floors referred to. The cost of the floors has been, under these conditions, about 38 cents (say 1s. 7d.) per square foot.

The new buildings for the United States Department of Agriculture are in process of erection by a general contractor, under the writer's supervision. The original designs called for steel beams and terra-cotta flat arches. A change was made to a type of floor similar to that shown in *Fig.* 3, but considerably lighter than the one used at the War College, because of shorter spans.

A careful detailed estimate made by the contractor and the writer jointly indicated that, in about 212,000 square feet of floor, there was a sure saving of about $10,000 (£2,000), and a possible further saving of $10,000 (£2,000) dependent upon prompt deliveries of materials, good management on the part of the contractor, etc. He was required to make the Department an allowance of $10,000 (£2,000) in his contract price because of the change. At the time of writing, it looks as though he would easily save the other $10,000 (£2,000) for himself. The total cost of the floors under the original design was figured at about $85,000 (£17,000).

In the better class of dwelling houses, and in small hotels and apartment houses, as well as in more important buildings, the small extra cost of reinforced concrete floors and partitions, as compared with timber construction, is more than repaid by the absence of cracks and settlements due to the shrinkage in the timber, which is inevitable in the highly-heated houses and buildings and the dry atmosphere often prevailing in the United States.

The rigidity and monolithic nature of reinforced concrete, its cheapness, durability, and its fire-resisting properties, if the bars be properly protected and a suitable aggregate used, give it many advantages. Its disadvantages in comparison with steel skeleton construction are, for tall buildings, the time required to erect it, and, in all buildings, the time required for it to dry out enough to permit of the application of wooden finish ; further, the unsatisfactory nature of the details so far worked out for connecting columns, beams, and girders, when heavy accumulated loads must be carried. Recent rapid progress on several buildings of moderate size indicates that the time of erection may yet be brought within economical limits, for even very tall buildings. Some system of manufacturing the members and putting them in place after they have set, with wet material used only for binding them together, may solve the question of slow drying, and engineering ingenuity can be depended upon to solve all problems as to satisfactory details. So, it may be said that for buildings of moderate height and some importance, reinforced concrete seems sure to occupy the field to the exclusion of all other types of construction ; and it may eventually even drive out steel skeleton designs for very tall buildings, for already one sixteen-story building has been erected in reinforced concrete, and the writer understands that one of eighteen stories is under way in Cincinnati, Ohio. These buildings seem a little venturesome in the present state of the art, and the published details of the completed one are not above criticism. But in this case, as in war, probably success justifies anything ; and the building undeniably stands without the slightest sign of weakness or failure, so far as can be determined by a casual inspection.



Reinforced Concrete Piles IN Tidal Waters.

By A. T. WALMISLEY, M.Inst.C.E.

There are few uses to which reinforced concrete has been put, where its economic advantages are so obvious, as in the case of piles for tidal waters. Since time immemorial, the cost and inconvenience of renewing timber piles has been common knowledge to the most uninitiated. Nevertheless, the introduction of the reinforced concrete pile has been remarkably slow, for it is now close on forty years since it was first proposed, and several designs were made the subject of patents. In actual practice, various types of reinforced concrete piles have been found eminently efficient, and time has also demonstrated that even the earlier imperfect examples were superior to timber piles. In the following article numerous forms of concrete piles are described. Correspondence is invited relative to early examples, and particulars (preferably accompanied by photographs) are especially welcome. The standardization of concrete aggregates suitable for piles in tidal waters would be materially facilitated if such data were collated for presentation in these columns.—ED.

THE bearing power of timber piles has long been acknowledged by engineers, but unless protected by a preservative, they are found in certain positions to be attacked by small destructive worms, and in situations where they are alternately exposed to wet and dry conditions, due to rise and fall of the tide, to become decayed. Creosote has been used as a preservative, but it is questionable whether it penetrates sufficiently below the surface to be effective, and directly a bolt hole is drilled or bored in a creosoted timber pile, a door is opened for the destructive agency to enter. A few years ago some creosoted piles were removed from the West Pier at Leith, and some non-creosoted piles from Granton Pier in the same tidal water. In both cases piles of Baltic fir were found to have been destroyed by the borings of a small crustacean, called the gribble (*Linmoria terebraus*). The surface of the Granton piles, which were not treated by any poisonous antiseptic, had been seriously attacked, and in the case of the Leith piles, the fresh wood beneath the creosoted surface had also been attacked by entry at a point where the pile had received a blow. In some creosoted elm piles at the same places the action varied from that in fir piles, since inspection showed that the gribble preferred the less resinous or softer portions of the fir. The *linmoria* is known to bore many kinds of timber. Teak, however, resists its action for a longer time, and Tasmanian blue gum is practically impervious to its attack. Greenheart timber is heavy, strong, and capable of resisting this destructive action, but is difficult to obtain in suitable lengths required for piles in modern engineering works. Pitch pine piles and Oregon piles, creosoted, have been employed, but require renewal after comparatively few years, and in deep water, subject to strong currents, need to be weighted with iron. Blue gum piles are heavy ; in fact they need to be buoyed up to enable them to float. In the temporary staging of the Admiralty Harbour Works at Dover there are some blue gum piles, 20 in. by 20 in., which have been drawn by Messrs. S. Pearson and Son, Government Contractors, and re-used four and five times in the extension of the staging. The specific gravity of Tasmanian blue gum (*Eucalyptus globulus*) is 1.2, so that if a pile should be struck by wreckage, it will, immediately after detachment, commence to sink, and not float about to effect other damage.

SOME ADVANTAGES OF REINFORCED CONCRETE PILES.

As stated at the commencement of this article, timber piles in tidal waters suffer considerably by the attack of sea worms and other destructive agencies, and for this reason reinforced concrete piles are now being extensively used on all parts of the coast. The idea is by no means new, for as long ago as 1869, M. François Coignet, of Paris, suggested the reinforced concrete pile, and in 1871 letters patent were granted to Mr. Philip Brannon of this country for piles of this description.

It will be understood that all structures such as wharves, quays, and jetties are liable to shock from vessels coming alongside, but owing to the elasticity of reinforced concrete they are less likely to be damaged than timber piles, and are readily repaired.

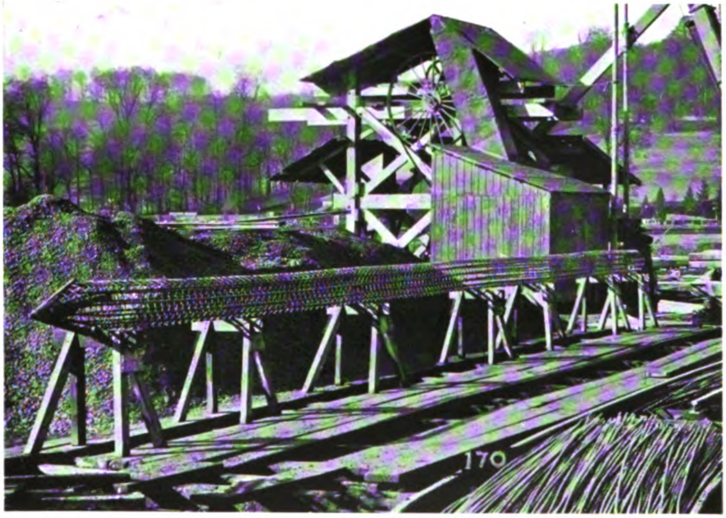


FIG. 1. "COIGNET" PILES IN COURSE OF PREPARATION AT BRISTOL DOCKS.

Under some conditions masonry, as applied to dock and harbour work, is not free from disadvantages, among which is settlement owing to instability of the foundations. In many cases, heavy masonry walls are built on alluvial soil, necessitating the driving of piles to provide a firm foundation for the footings. The necessity for driving piles to great depths increases the cost of the work, but timber piles do not always give entirely satisfactory results.

The principal advantages claimed for reinforced concrete piles as applied in tidal waters are that they can be moulded to any required length and section, and that they can be driven practically to any depth as continuous or sheet piles. Reinforced concrete sheet piles form a watertight barrier, which can be proportioned to resist any required pressure, and as the watertight wall is carried down to the whole depth of the piles no disturbance can arise such as might occur below the base of an ordinary wall.

VARIETIES OF REINFORCED CONCRETE PILES.

In most of the reinforced concrete piles hitherto made the reinforcement consists of longitudinal bars connected or tied together by means of transverse bars or rods, and in one or two cases a spiral winding of thin rods has been applied. Expanded metal has also been employed with considerable success. Rolled joists are not a section originally intended for reinforced concrete, for when they are used, the metal is too much concentrated in one position, and they are only applicable to large reinforced sections. Nevertheless, for pile-work, the insertion of rolled joists possesses some merit. The manufacture of concrete piles is constantly being improved by various specialists, and is scarcely sufficiently advanced at present for a standard system to be recommended.

Reinforced concrete piles of the Hennebique type have been very largely used in this country in ordinary piled foundations and in sheet piling. The Coignet system piles have been chiefly employed on the Continent, but are now being introduced into Great Britain. Another form of reinforced concrete pile, which has been adopted for dock and wharf construction on the Thames, is that designed by Mr. A. E. Williams, A.M.Inst.C.E., of Dagenham Docks, Essex. These and some well-known forms of concrete piles adopted in the United States are described later in the present article.

FIGS. 2 AND 3. "COIGNET" PILES BEING MOULDED AT BRISTOL DOCKS.

In a recent treatise on "Concrete Steel," by Mr. W. Noble Twelvetrees, published by Messrs. Whittaker and Co., the subject of concrete steel piles in harbour and river work in bridge building, is briefly but ably dealt with, and the author mentions some piles employed at Rotherhithe in which the longitudinal reinforcement was formed by steel angle bars, 2 in. by 2 in. by $\frac{3}{8}$ in., connected horizontally with $1\frac{1}{4}$ in. by $\frac{3}{16}$ in. flat bars at intervals in a 40 ft. to 50 ft. length. Also diaphragm bars of $\frac{1}{8}$ in. steel wire. The lower end of the pile is furnished with a securely attached steel point. These piles are of the type designed by Mr. Andrew Johnston, M.Inst.C.E. M. Considère employs hooped concrete in which a thin rod or thick wire is wound spirally round vertical rods, equally spaced from the centre of the section. It is claimed that a unit stress of 2,000 lb. per square inch may be allowed for hooped concrete, as against (say) 400 lb. per square inch for concrete in compression.

In driving concrete piles the head of the pile is usually protected from injury by covering it with a helmet or iron case filled with sawdust, and a timber dolly is invariably used. Arrangements can be made for assisting the driving when required by means of a water jet at the necessary pressure to force out any sand entering the grooves formed on the sides of sheet piling.

"COIGNET" PILES.

M. Edmond Coignet, of Paris, recognising the value of concrete in foundations, began by making piles hollow and without any steel. Water under pressure was injected into the interior of the pile, so as to help the driving operations. Later on, however, he tried piles of circular section with two longitudinal facings for guiding purposes. These piles were not hollow. The framework was made of longitudinal bars, bound by rings about $\frac{1}{4}$ in. diameter, and having the ends of each ring bent in, so as to alternately secure two of the longitudinal bars. He also tried another method, consisting in simply winding round this a $\frac{1}{4}$ in. rod in a spiral manner, every intersection being bound with annealed wire.

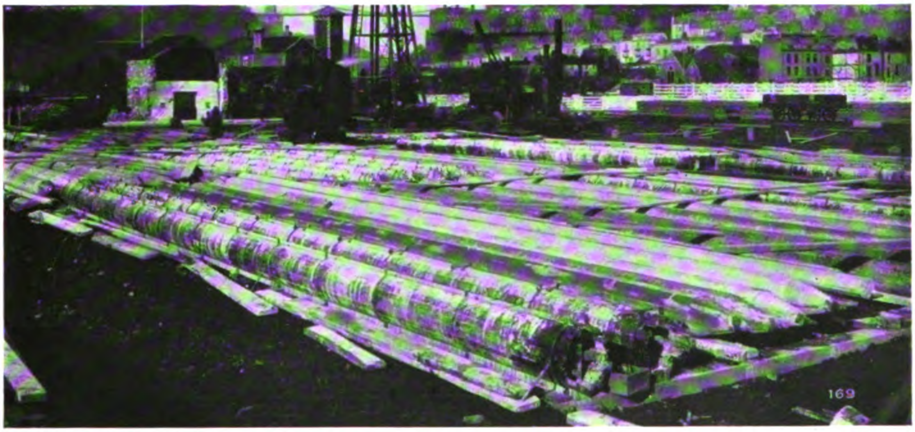
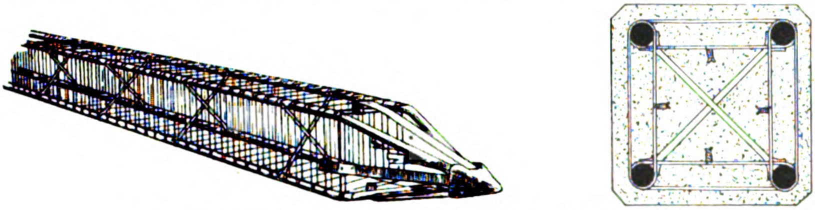


FIG. 4. "COIGNET" PILES SEASONING AT CONTRACTOR'S YARD, BRISTOL DOCKS.

In order to prevent any unwinding of this spiral tie-rod, and to give more rigidity to the framework, another spiral wire or rod of smaller diameter than the above is introduced, running in a reverse direction or twist, and having a pitch of about 4 or 5 ft. The safe load on one of these piles was reckoned as 60 tons, but, as a result of a test made by the engineers to the Belgian Government, piles about 40 ft. long and about 12 in. diameter, with flat longitudinal facings of about 6 in., were driven by rams of various weights, and a single pile was found capable of sustaining 4,320 blows of a ram weighing $\frac{1}{2}$ to 1 ton; while another pile sustained 3,840 blows of a "Morisson" ram at a rate of 120 blows per minute. The heads of these piles were not even chipped, and after being loaded with weights varying from 25 to 60 tons, they were drawn out and found to be without any cracks and quite as good as when unused. In a large warehouse under construction at Bristol by Messrs. W. Cowlin and Son, about 600 spirally-reinforced piles of the "Coignet" type, having a diameter of 14 in. to 15 in., 52 ft. long, were driven with a ram weighing over 2 tons. These piles weigh about 4 tons each, and they are terminated by a circular shoe made of wrought iron.



FIGS. 5 AND 6. DETAILS OF "HENNEBIQUE" PILES.

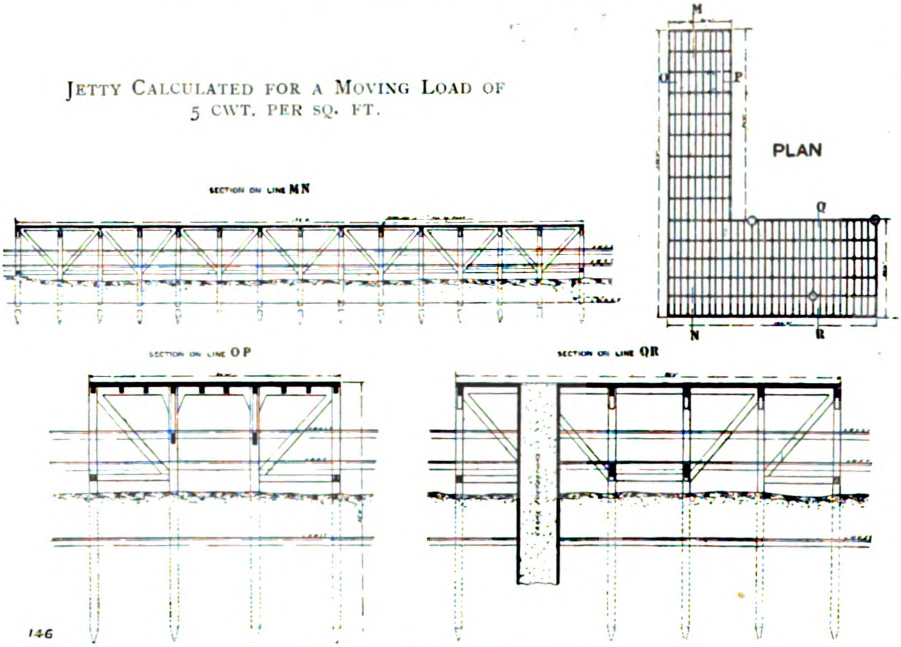


FIG. 7. JETTY AT WOOLSTON.

In spite of their weight, they are handled without difficulty by a travelling crane, and the ground in which these piles are driven is at Bristol subjected to continual dampness, being practically mud and surrounded by a tidal river. A landing stage is also to be erected with the use of this system of armoured concrete piles. The concrete beams and wailings are made in advance so as to permit of connection at low water as simultaneously as possible with the fixing of the pile, and, by being grouted at as low a level as possible to the piles, form a continuous structure. The upper and lower parallel members of these beams and wailings are bound by ties, which arrangement allows them to be lifted and lowered without fracture. *Figs.* 1 to 4 illustrate the process of pile making in various stages. In *Fig.* 1 is the metal framework ready for concreting; *Fig.* 2 shows the framework enclosed by the horizontal moulds; *Fig.* 3 the mould filled with concrete and closed at the top; and *Fig.* 4 some finished piles. The framework is carefully suspended in an interior defined position in the moulds, and the concrete is rammed in between the bars. The two circular moulds are removed twenty-four hours after the concreting is finished and applied for another

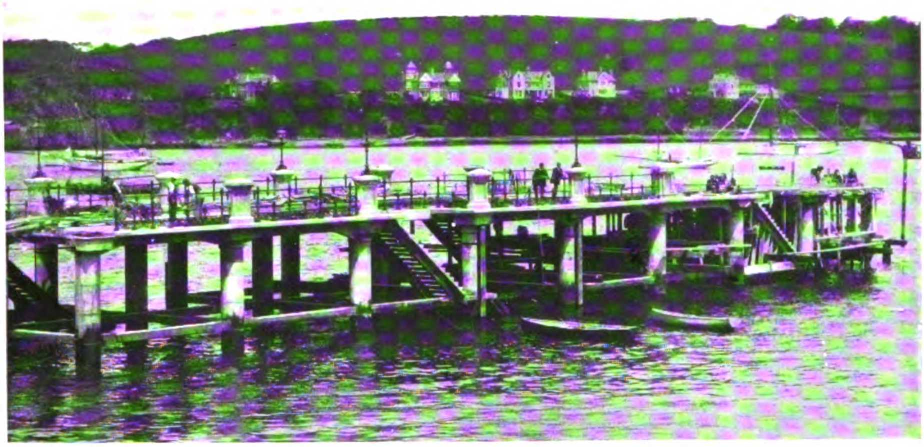


FIG. 8. PIER AT FALMOUTH.

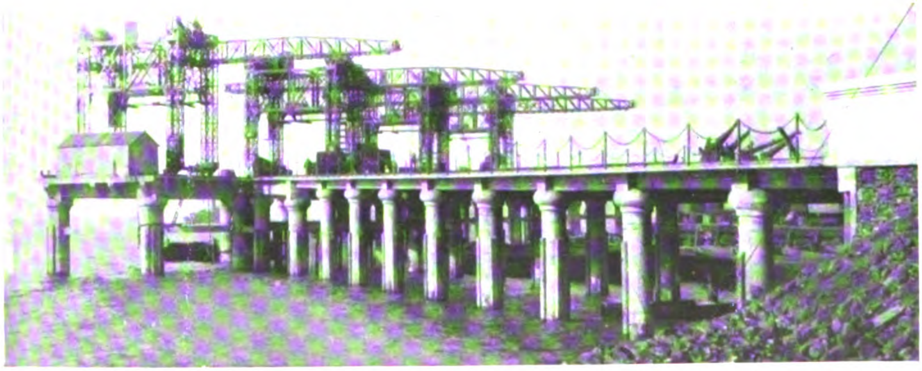
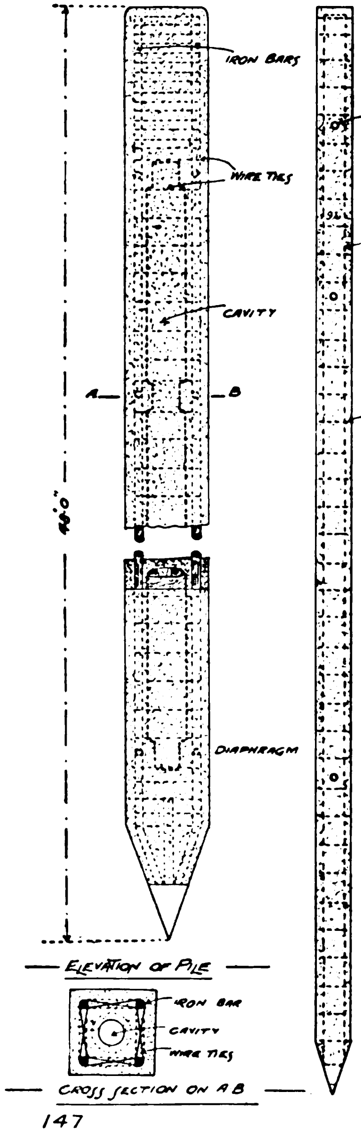
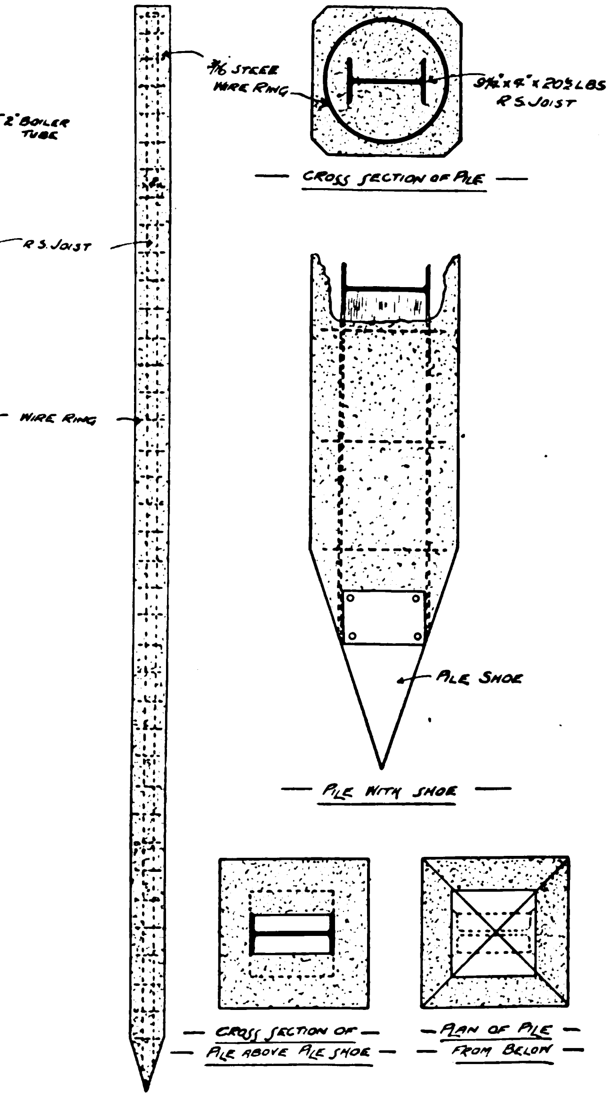


FIG. 9. JETTY AT DAGENHAM.

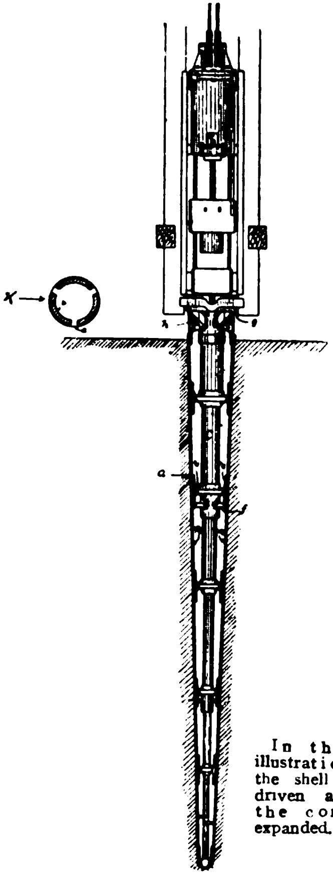
pile. Each pile remains on the sill on which it has been made until it is sufficiently hard to permit of shifting. After six weeks' rest, a pile is deemed ready for driving. A special cap made of wood resting on shavings and sawdust, maintained by a metal envelope, prevents the chipping of the concrete while being driven, and the concrete consists of Portland cement, river sand, and broken granite carefully selected and mechanically mixed.



FIGS. 10, 11, AND 12.
DETAILS OF "HENNEBIQUE" PILES.
(Mouchel type).

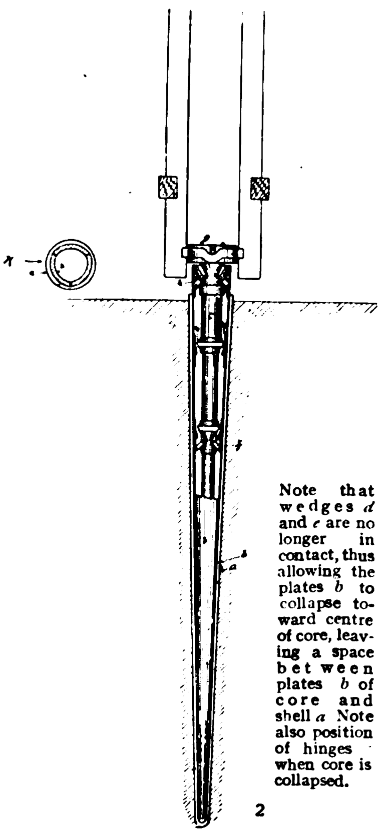


FIGS. 14 TO 18.
DETAILS OF "WILLIAMS" PILES.



In this illustration the shell is driven and the core expanded.

Fig. 19. Sectional pile core, showing collapsing and expanding device. (Steam hammer in the leads resting upon the core.



Note that wedges *d* and *e* are no longer in contact, thus allowing the plates *b* to collapse toward centre of core, leaving a space between plates *b* of core and shell *a* Note also position of hinges when core is collapsed.

Fig. 20. Section of pile core collapsed and ready to withdraw from the shell.

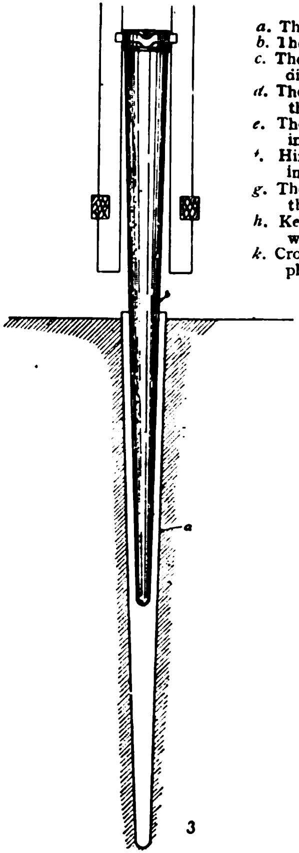


Fig. 21. Pile core collapsed and partly withdrawn from the shell.

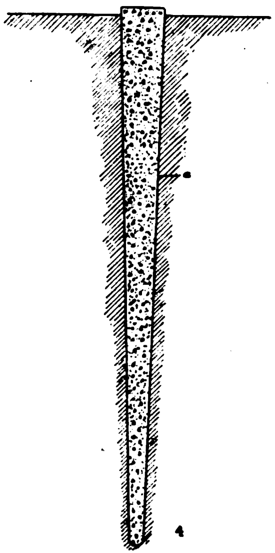


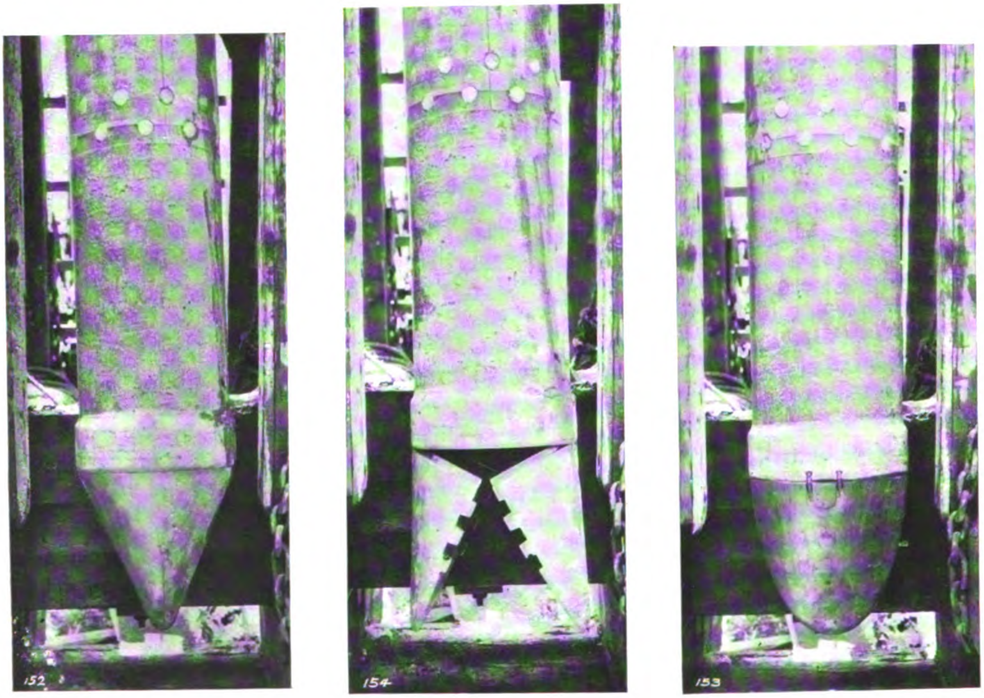
Fig. 22. Concrete Pile without reinforcement.

a. The shell driven in the ground.
b. The exterior plates of the pile core.
c. The stem of pile core of diminishing diameter.
d. The wedge-shaped castings fitted to the exterior plates.
e. The corresponding wedges fitted to the interior stem.
f. Hinges linking the exterior plates and interior stem of the core.
g. The head of the core, hollowed out at the top to receive an oak cap block.
h. Keys to keep the exterior plates in place when expanded.
k. Cross section showing opening between plates to allow for collapsing.

FIGS. 19 TO 22. THE "RAYMOND" PILE.

"HENNEBIQUE" PILES.

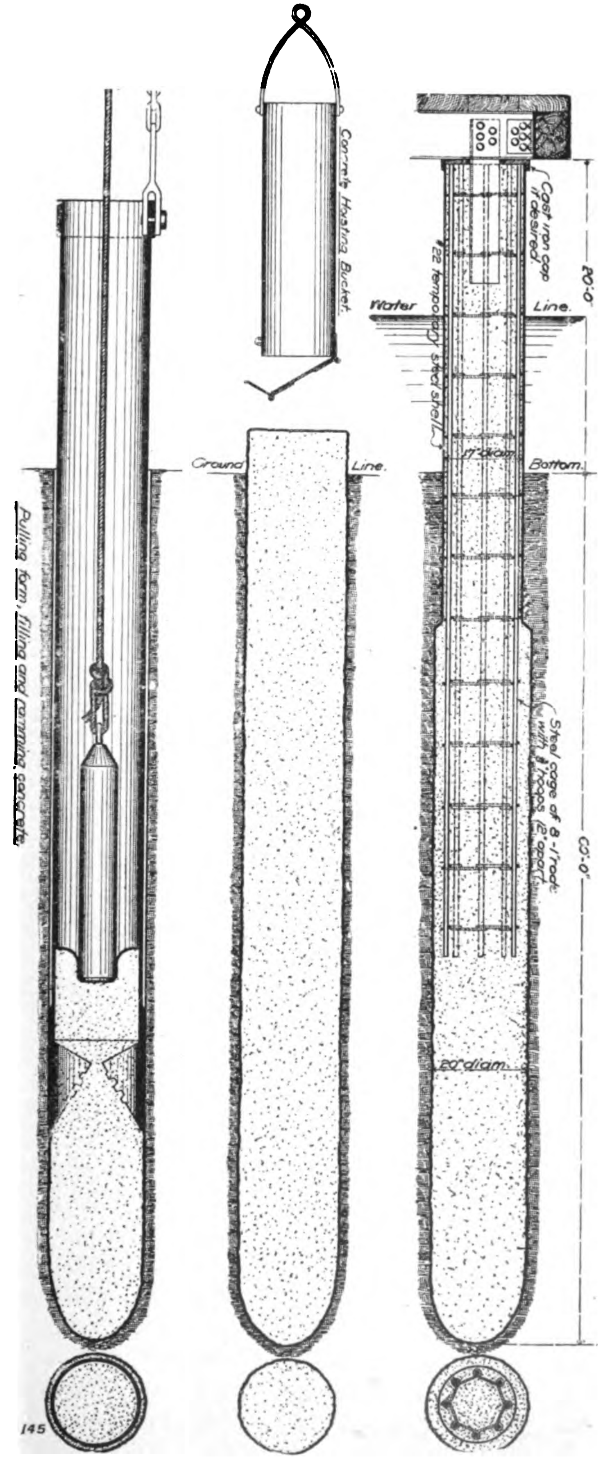
Piles on the Hennebique system are moulded in rich Portland cement concrete, strengthened with iron or steel rods, the diameter and arrangement of which depends on the nature of the work, and provided with pointed iron or steel shoes. The rods, being encased in concrete, are preserved against decay. The piles can be prepared in advance, thus being thoroughly set when required for driving in position. *Figs.* 5 and 6 exhibit the ordinary type of Hennebique pile. The lateral binding at intervals, tends to obviate any splitting of the pile in the process of driving. Sheet piles are constructed similarly to ordinary piles, except that they have wedge-shaped shoes, to provide that each pile fits close to its neighbour. On each side of the sheet pile is a semi-circular groove, the grooves of two consecutive piles forming a cylinder, which is filled with fine concrete, and joining the piles together to form a watertight wall.



Jaws closed—ready for driving. Jaws open—pile completed. Jaws closed—ready for driving.

FIGS. 27, 28, 29. ALLIGATOR DRIVING FORM FOR "SIMPLEX" PILE.

Fig 7 contains a plan and sections of a jetty built with piles of this type at Woolston, near Southampton, the platform being designed for a moving load of 5 cwt. per square foot. Two other interesting examples of similar construction are furnished by the Prince of Wales Pier, Falmouth (*Fig.* 8), and a jetty recently built on the Thames, at Dagenham (*Fig.* 9), The former structure is built on 14 in. by 14 in. piles, and is of a total length of 318 ft., the approach being


Pulling form, filling and ramming concrete.
Concrete Hoisting Bucket.
Ground Line.
Water Line.
Cast iron cap if desired.
#22 temporary steel shell
17" diam.
Bottom.
20'0"
Steel cage of 8-1" rods with ⅜" hoops 12" apart
60'-0"
20" diam.
145

Alligator Point driving form in operation. Simplex Pile not reinforced. Simplex Pile reinforced.

FIGS. 24 TO 26. "SIMPLEX" PILES.

118 ft. 6 in. long, and the pier proper 200 ft. by 36 ft. wide. This work is from the designs of Mr. W. H. Tresidder, borough engineer of Falmouth.

The durability of this form of pile is shown by the examination of several pile heads, cut some seven years ago from a work at Southampton during construction, and since then, resting on the foreshore exposed and covered alternately by the tide four times each day, which were recovered and examined by various engineers to determine the effect of sea water on the steel. Although the protruding portions of the steel were completely rotted by the action of the salt water, the part surrounded by concrete was found as bright as when it left the rolling mill, and this preservation was found complete at a depth of only ½ in. under the protecting envelope of concrete.

Hollow reinforced piles on the Hennebique system (Mouchel's type) are illustrated by the sections in *Figs.* 10, 11 and 12, and consist of light hollow piles, vertically reinforced with iron bars of circular section, to which are connected at the required intervals the horizontal reinforcement, consisting of iron diaphragms, distance pieces and wire ties. The cavities in this pile are formed of concrete moulds built in during manufacture. They are lighter, and, therefore, offer special facilities for handling and transport.

When a junction has to be formed, extra iron or steel bars can be added by overlapping for a distance equal to twenty-four times their diameter. Another method is to cut off the ends of the rods die-square, and butt them against one another, adding a sleeve of iron tubing over the joint, thus ensuring a uniform resistance. The tops of the vertical rods are usually covered with about 1½ in. of concrete. *Fig.* 13 on this page illustrates the method of fixing reinforced cylinders around the heads of a group of piles.

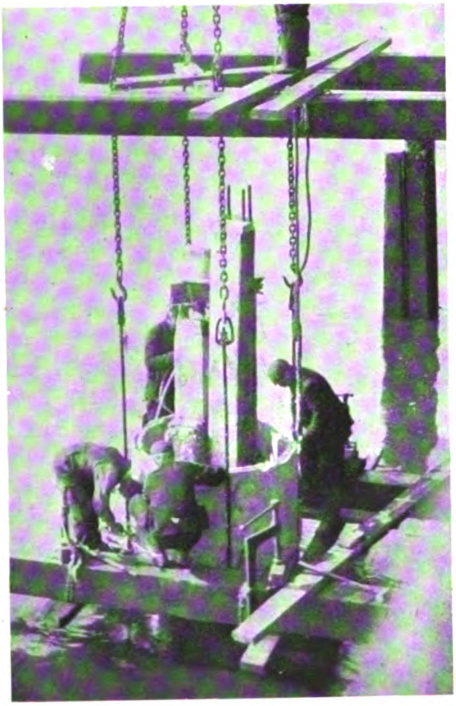


FIG. 13.

"WILLIAMS'" PILES.

The main feature of the Williams' system of concrete steel piles, of which full details are given in *Figs.* 14 to 18, is the use of a rolled steel joist in the centre. This joist may be fitted with a cast-iron shoe, but it is considered preferable to cut a triangular piece out of the web of the joist, and to bend the flanges in until they meet, cutting off the corners to form a point. The top of the joist is covered by about 2 in. of concrete, and the web is drilled with six holes.

Rings of steel wire are placed around the joist at intervals of about 12 in., and embedded in the concrete.

Three pieces of 2 in. boiler tube are passed through holes drilled down the centre line of the web, and extend to the outside of the concrete. The first of these is 2 ft. from the top of the pile, and is used both as a gauge bolt hole and also for pitching the pile. The other two pipes are situated at points respectively one-quarter of the total length of the piles on each side of its centre, and are used for slinging in a horizontal position.

Joints are formed by breaking away the concrete from the joists for a depth of about 18 in.; a piece of joist is then added of the required length, and fish-plated to the driven pile. Moulds are then framed round, and the concrete is rammed in, making a continuous pile from the point to the top of the work. This construction cannot be regarded as a reinforced concrete pile, as it is really a steel pile protected by concrete, whereas a reinforced concrete pile is really a concrete pile reinforced by steel, and concrete is the chief component whereas in Williams' pile the steel joist is the chief component of the construction. When flexure is likely to be set up, the pile is stiffened by the addition of two flat steel bars on either side. Driving is performed by the usual machines, but, as with other systems combining concrete, the head of the pile is protected by a temporary cast steel cap. fitted on the underside with a sawdust pad, and on the upperside with a hard wood dolly, about 3 ft. long, to receive the blow of the ram. A 40 cwt. ram, falling 6 ft. is generally used, but 8 ft. blows have been repeatedly given without damaging the pile.

"RAYMOND" PILES.

Since their introduction, in 1901, Raymond concrete piles have been used in the United States, and have proved of value in soils of all kinds.

This type of concrete pile is inserted either by the jetting method or the pile core method. The jetting method is adaptable only to such soils as sand, quicksand, and silt that will flow readily under a water jet. The pile core method, which is more generally used for foundation work, may be briefly described as follows: A collapsible steel pile core, conical in shape, is encased in a thin, tight-fitting metal shell. The core and shell are driven into the ground by means of a pile driver, preferably fitted with a steam hammer. The core is so constructed that when the desired depth has been reached it is collapsed and loses contact with the shell, so that it can be easily withdrawn, leaving the shell in the ground to act as a mould for the concrete and to prevent the admixture of extraneous matter. When the core has been withdrawn, the shell is filled with concrete, well tamped during the filling process.

Fig. 16 is a sectional view of the Raymond pile core, showing the collapsing and expanding device, and a steam hammer in the leads resting upon the core. In this illustration the shell is driven and the core expanded. *Fig.* 20 is a sectional view of the pile core collapsed, and ready to be withdrawn from the shell. *Fig.* 21 shows the pile core collapsed, and partly withdrawn from the shell. *Fig.* 22 represents a completed concrete pile without reinforcement.

"SIMPLEX" PILES.

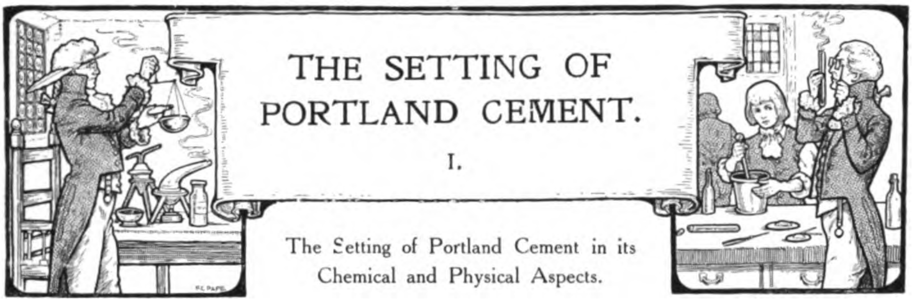
The Simplex pile contains expanded metal for its reinforcement, employed in the form of a circumferential cylinder of (say) 3 in. mesh by $\frac{1}{16}$ in. thickness. *Figs.* 24 to 26 comprise three sections of the Simplex pile, one showing the driving form in operation, and the two others a plain concrete pile for sea walls, and a reinforced concrete pile for wharves and docks, respectively. A vertical cylinder of expanded metal (provided the diameter of the cylinder is large enough to enable the expanded metal sheet to be bent to the circle desired) is a very efficient method for holding the concrete to form a pile, and when once the cylinder is formed, dispenses with the superintendence in manufacture needed for the disposition of separate members of other types of reinforcement. Thus maintained, the concrete is prevented from splintering in the process of driving. For hollow cylindrical foundations, to be afterwards filled with concrete, expanded metal would form a suitable reinforcement for the concreted wells. The alligators are shown on *Figs.* 27 to 29.

An interesting account of the manner in which the difficulties presented by water-bearing strata were overcome by applying this system is given in a paper on "Reinforced Concrete Piling," read at the Incorporated

Association of Municipal and County Engineers' meeting at Norwich, in 1905, by Mr. A. R. Galbraith. A wrought-iron shell or tube, the internal section of which corresponds to the length and diameter of the size of the pile, is introduced, having a cast concrete shoe affixed at its lower end. The expanded metal reinforcement is adjusted in the interior of this shell, and rests on this concrete shoe. The shell is withdrawn, while the process of concrete filling advances. In the water-bearing strata an outer shell was made long enough to penetrate the bottom a sufficient distance to prevent the percolation of water into the hole, and was driven, together with the inner shell, surmounted with a hardwood cap. The inner shell was gradually withdrawn, leaving the outer shell in place by unfastening a clamped collar by which they are connected together. The outer shell then remained, forming a permanent protection for the portion of the pile exposed to the action of water. The forms comprising the shells were 11 ft. long, made of boiler steel, $\frac{3}{8}$ in. thick, and the shells could be raised when the concrete had set. The interior shell consisted of a cast-iron pipe, the lower end of this pipe fitting over a tenon round the upper portion of the concrete shoe, the upper end being crowned by a black ash driving cap, so placed as to drive the combined shells. In withdrawing the inner shell the process was so gradual that there was never less than 6 in. of concrete remaining below its lower edge. The friction on the surface of contact was overcome by applying a lubricating coat of grease or heavy oil prior to driving. In this way, concrete piles were substituted for deep trenches filled with solid concrete, and the system is suggestive, if not sufficiently satisfactory in detail, for imitation in similar cases. This form of pile was used in the foundations of the Engineering School at Washington Barracks, Columbia, where they were constructed 17 in. diameter by 35 ft. long.

CONCLUSION.

In connection with design of all reinforced concrete piles, it must be remembered that concrete adheres more firmly to iron or steel when left with its natural surface and not treated by any anti-rust process. Hence steel embedded in concrete should not be coated in any way. Exposed iron is a source of weakness in a structure, but when surrounded with good concrete, it is not subject to alternate conditions of dryness and moisture, and there is no reason to fear it will gradually corrode. Indeed, experience shows that, being free from atmospheric changes, it does not sustain detriment if sea sand and sea water are eliminated in the construction.



THE SETTING OF PORTLAND CEMENT.

I.

The Setting of Portland Cement in its Chemical and Physical Aspects.

By CECIL H. DESCH, D.Sc., Ph.D.

To all engaged in constructional engineering, and more particularly in the application of concrete and reinforced concrete, the question of the setting of Portland cement is one of the utmost importance. Having regard to this, arrangements have been made by which a series of articles will be presented by well-known authorities at home and abroad, dealing with the question in its chemical and physical aspects, and these various articles will finally be summarised with the view of presenting the more important facts and the consensus of opinion. The attention accorded to the earlier article has encouraged us to extend our list of contributors on this subject to the leading authorities of Germany and the United States. Correspondence is invited, as a free discussion of the various arguments put forward will be welcome to all who have this subject at heart.—ED.

PART B.

THE chemical changes taking place during the processes of setting and hardening of cement having been discussed in the first paper, so far as the imperfect state of our present knowledge allows them to be put into definite form, we have now to consider the physical changes which accompany the chemical reactions, and result in the transformation of the original plastic mass into a hard, resistant solid, and as before, it will be well, before proceeding with the somewhat complex case of Portland cement, to consider the conditions which prevail in the simpler case of the setting of plaster of Paris. The phenomena concerned are those of solution and crystallisation, and it is in the behaviour of so-called "supersaturated" solutions that their explanation is to be found. The chemical reaction involved is, as was shown in the first paper, one of simple hydration, being represented by the equation :—

$$CaSO_4, \tfrac{1}{2}H_2O + 1\tfrac{1}{2}H_2O = CaSO_4, 2H_2O.$$

The hemihydrate, which constitutes the bulk of ordinary, well-burnt plaster, consists of minute, prismatic crystals. On being brought into contact with water, as in the mixing of the plaster, these crystals begin to dissolve, the fine state of division in which the hemihydrate occurs in a good plaster facilitating the process of solution, so that saturation takes place rapidly in the neighbourhood of the solid. Now it is a general principle of chemical equilibrium that when a substance can exist in two modifications, the one being stable and the other unstable at a given temperature, the unstable modification has the greater solubility. In accordance with this law we find that the unstable hemihydrate has at ordinary temperatures a greater solubility in water than the stable dihydrate (gypsum). A saturated solution of the hemihydrate is therefore supersaturated with respect to the dihydrate. That this is so is easily demonstrated by a simple experiment. On stirring burnt plaster with water and filtering after about five minutes, a clear solution is obtained, which, however, rapidly becomes cloudy and deposits crystals of gypsum. The same thing occurs in the ordinary process of mixing plaster with water. The quantity of water used is of course only a minute fraction of that which would be necessary to dissolve the whole of the plaster, but the process takes place continuously, the solution in the neighbourhood of each solid particle becoming saturated with hemihydrate, then depositing crystals of dihydrate, and so becoming able to dissolve more hemihydrate and so on, the cycle of changes continuing until the whole of the original plaster is converted into the stable gypsum. The process takes place with development of heat and the separation of crystals is accompanied by a slight increase of volume, which accounts for the well-known property of plaster of Paris, of accurately filling and taking the impression of the mould in which it is cast.

The natural crystalline form of the dihydrate is that of narrow, monoclinic prisms. When deposited under the conditions described, these crystals are grouped about a central nucleus, the elongated prisms radiating in all directions. Such an arrangement is eminently favourable to the production of a mechanically strong mass, the spherical bundles approaching one another as the crystallisation proceeds, and the radiating crystals becoming entangled and interlocked. When the conditions are such that this particular structure is not obtained, as, for instance, when dilute alcohol is used instead of water, the crystalline prisms of gypsum remain unattached, and although they become felted together, the mass thus produced is devoid of mechanical strength.

A somewhat different view of the mechanism of the process is taken by Rohland, who considers that the setting consists essentially in the formation of a solid solution of gypsum and water. This assumption is not, however, supported by any direct evidence of the existence of such a solid solution in hardened plaster. The fact mentioned by Rohland, that plaster does not harden when gelatine solution is used instead of water, the process of diffusion necsssary to produce a solid solution being thus hindered, is sufficiently accounted for by the well-known fact that the development of crystals is modified and retarded by the presence of a viscuous medium, particularly of colloidal character.

Another phenomenon of great importance in the setting of cements may also be most simply studied in the case of plaster of Paris. This is the influence of the presence of foreign substances on the rate of setting. Since the process depends on the formation of the supersaturated solution of the hemihydrate, the addition of salts which increase the solubility of that compound also increases the velocity of hydration, and salts whose presence diminishes the solubility also reduce the velocity. The first class may be called positive, the second negative, catalytic agents.

We may now pass to the consideration of the case of Portland cement. As we have seen. the setting process is here also one of hydration, the aluminates and silicates first taking up water and then undergoing hydrolysis, calcium hydroxide being set free and a solid residue of less basic hydrated aluminates and silicates remaining.

Certain of the aluminates react readily with water, bringing about the initial set of the cement ; the silicates are more sluggish, and only react slowly after setting has occurred, but the physical nature of the process is the same in both cases, and for convenience both may be considered together.

Here, as in the case of calcium sulphate, the first condition of the setting is the formation of a solution, supersaturated with respect to one constituent. The aluminate or silicate dissolves in water in the first place integrally, producing an unstable solution which becomes saturated in the neighbourhood of the solid particles from which it was formed. Hydrolysis then takes place, and the quantity of calcium hydroxide produced being in excess of that necessary to form a saturated solution, a portion crystallises out. A Portland cement after setting is therefore found to consist in large part of clear crystals of calcium hydroxide $Ca(OH)_2$, which may attain a considerable size when the hydration has been sufficiently slow. Along with these, small crystals of other constituents may be recognised in a microscopic examination of the hardened cement, such crystals representing silicates and aluminates whose composition cannot at present be determined with accuracy, but which are of importance in determining the mechanical properties of the cement mass.

Calcium hydroxide only forms crystals when deposited from solution, either by the slow evaporation of lime water or by the hydrolysis of a basic calcium compound. When obtained by the action of water on lime, it forms an amorphous mass. In the well-known slaking of well-burnt quick lime, the hydration takes place rapidly, with great development of heat. During hydration the particles are violently forced apart, giving rise to a great increase of volume of the mass, a property which is made use of in lime cartridges, etc. This curious effect is purely mechanical, and is comparable with a number of similar phenomena known to inorganic chemists. So far from any real expansion of the constituents themselves taking place, the reaction $CaO + H_2O = Ca(OH)_2$ is actually accompanied by a diminution of volume, the apparent increase representing only the distance by which the particles succeed in separating themselves. In the hydrolysis of basic calcium compounds, however, this apparent expansion does not take place, and although the change is accompanied by the development of heat, the reaction proceeds so slowly that the rise of temperature produced is only small. The cause of the well-known bad effects due to the presence of "free lime" in Portland cement is now obvious. Such lime as is not held in combination with silica and alumina (or, if we adopt Rohland's view, as is not retained in solid solution in the mass) behaves like a sluggish quicklime, hydrating to form an amorphous product, undergoing the process of apparent expansion described above, and therefore bringing about cracking of the cement after setting. It is on this fact that "expansion tests," such as that of Le Chatelier, are based.

For the cement user it is of the greatest importance that all the lime present in the cement shall be held in such a state of solution or of combination as to undergo only this slow and gradual hydration, with the formation of crystalline calcium hydroxide. As shown in the first paper, the fulfilment of this condition depends not only on the ultimate chemical composition of the cement, but also

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To the brief list of important papers on this subject on p. 44, No. 1, Vol. I., should be added:—Clifford Richardson: Constitution of Portland Cement from a Physico-Chemical Standpoint. Atlantic City, N.J., 1904.

on the degree of completeness with which the constituents have reacted together in the kiln, this again being determined by the fineness of grinding of the original mixture and by the temperature at which the pyrochemical reactions have taken place.

The velocity of hydration of the basic constituents varies with the temperature at which the reaction takes place, increasing rapidly with rising temperature. The " setting time " of a cement has therefore a definite meaning only when the temperature of the water used (and that of the surrounding air) is specified. The slow hydrolysis of the silicates which gives rise to the ultimate hardening of the cement is less sensitive to this influence than are the rapid processes of hydrolysis involved in setting, and further, quick-setting cements are more affected by the temperature of the water used in mixing than slow-setting va ieties. The presence of catalytic agents also modifies the velocity of hydration, as in the case of plaster of Paris, although the chemical reactions concerned in the setting of the two materials being very different, it is not possible to predict the effect of a given salt in accelerating or retarding the setting of Portland cement from its observed influence on the corresponding process in plaster. Catalytic agents capable of modifying the reaction may be present in the water employed, or may already exist as subordinate constituents of the cement. Of the latter class are alkali salts derived from the clay used in the manufacture, and calcium sulphate. This compound exercises a retarding influence on the setting, and it is therefore a common practice to add a small proportion of gypsum to Portland cement which would otherwise set too rapidly for convenient use. The amount of acceleration or retardation produced usually increases with the quantity of the salt added, but is not proportional to it. In certain cases, even, a further increase of the catalytic agent beyond a certain limit may even bring about a reversal of the action, a positive catalyser thus becoming a negative, and *vice versa*. It is important to notice that compounds capable of exercising a marked catalytic influence may be formed by reactions within the cement itself. This is especially the case with the more or less unstable aluminium compounds derived from the clay. These undergo chemical changes during storage, and this fact explains many of the remarkable cases known to manufacturers, in which a slow-setting cement has changed spontaneously during storage into a quick-setting one, and conversely. A discussion of this most interesting class of chemical and physical changes would, however, lead us far beyond the limits of this paper.

It has only been possible in these few pages to give an outline of our present knowledge of the chemistry and physics of Portland cement. In spite of the large amount of work already published, the subject bristles with unsolved problems, many of which involve points of great scientific interest. The solution of those problems must necessarily react favourably on technical practice, and there is therefore a double motive for attacking them. Briefly, it may be said that those physico-chemical laboratory methods which have already done such good service in the study of salt solutions and of metallic alloys are those most likely to yield definite results in this field. Certain obscure phenomena of crystallisation, of great interest to the mineralogist, are also involved. It is to be hoped that the next few years will see great advances in these directions.

THE PRESERVATION OF IRON AND STEEL.

Part B.

By B. H. THWAITE, C.E.

The collapse of a part of the Charing Cross Terminus roof has again called attention to the absolute necessity of carefully preserving iron and steel from corrosion, a matter all too frequently neglected. In this article the causes and chemical aspects of corrosion are dealt with, as also the question of protection afforded respectively by (a) cement, (b) paint, and (c) solutions. The article has been divided into two parts, the first half appearing in the previous issue described the causes of corrosion and dealt with the protection afforded by Portland cement.—ED.

HAVING dealt with the importance of preserving steel from corrosion, and having pointed out the advantages of Portland cement and cement concrete as efficient preservatives, I must, however, confess that, unfortunately, some details of steel construction do not lend themselves readily to the application of cement or cement concrete, and that for this reason, it is also necessary to consider what other preservative methods are available, that at least afford some moderate protection, if regularly applied. Thus the question of protection by paint and by solutions also requires attention.

PAINT AN UNRELIABLE PRESERVATIVE.

The ordinary rust-preventing precautions adopted in the United States by steel-frame construction experts is probably well represented by the following extracts from two specifications.*

In the first, relating to the "Kuhne Building," New York, it is required that :—

> "The foundation grillage beams are to be painted with two coats of graphite paint "and the space between the beams and around them for a distance of 14 in. is to be filled "up with concrete."

In the second, referring to the new "Times Building," New York, it is provided that :—

> "All parts of the structural iron and steelwork must be painted with two coats "of red lead, all finished members must receive one complete coat of paint before they "are taken from the shop or exposed to the weather. Covered surfaces (surfaces in "contact and surfaces enclosed) of all parts of riveted members, should receive one "coat of paint before they are assembled. All accessible surfaces must have one coat "of paint after erection."
>
> "The first coat must not be applied over loose scale or over initial corrosion. If "the scale has not fallen off, or if rust has formed, it must be removed, if necessary, with "wire brushes. Painting must always be done on dry surfaces and preferably on warm "ones. Mud, grease, and dirt of every kind, must be thoroughly removed before

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* From Copies of Specifications kindly put at the disposal of the author by Mr. Croydon Purdy of New York, U.S.A.

"painting. Bolts remaining in the structure must be dipped in paint before being put "in place."

"All paint must be mixed in small quantities immediately before application, "and paint mixed, and not immediately applied, cannot afterwards be mixed with "fresh material. The first coat must be mixed in the proportion of one gallon of boiled "linseed oil to 33 lb. of red lead. The second coat must be mixed the same way, with "lamp black ground in oil, added in sufficient quantity to colour a light brown.

Whether the foregoing paint coverings will be adequately effective, time alone will tell. The writer is, however, of the opinion that no ordinary paint depending upon the oxidation of its driers for hardening, is even moderately impervious to either air or water.

The fact that the oxidation of the drier is supported only from the air outside the painted surfaces, obviously means that air must penetrate the latter during the hardening process for so long as any drier remains. Consequently, owing to the pores produced by the flow of air and by the volatile gases given off by the drier during evaporation, the paint cannot be impervious to air and moisture. Of course, the greater the number of coats, the less porous the paint will be, because the lines of the air pores will be broken, but when once air and moisture have secured a passage the effect of the local oxidation of the metal will be to lift the covering of the paint at the *locale* of air entrance, cracking the paint and allowing further air and moisture to pass to the metal, with the ultimate effect of lifting the paint from off a considerable part of the surface requiring protection.

Lately a special paint claimed to contain a considerable proportion of indiarubber has been put on the market, which, by reason of its claimed elasticity, should be less liable to crack than even the best of ordinary paints. This so-called "vulcanite" paint certainly merits attention amongst the best of the moderately impervious paint coverings.

Outside the Portland cement and cement concrete method of preservation, which should be applied whenever practicable, there is, however, no painting or other method in general use for steel-frame structures that can be said to afford really adequate protection against the culminating effects of oxidation or rusting.

TAR AND PITCH SOLUTIONS AS POSSIBLE PRESERVATIVES.

The writer, however, submits a proposal that he believes will provide considerable protection for steel structures against corrosion in any ordinary everyday environment. It is based on Dr. Angus Smith's process of treating cast-iron water pipes, which, if properly applied, gives most satisfactory results.

The ingredients used in the Angus Smith process,* consist of coal tar and pitch oil. These materials, mixed in the proportions of one part dead coal tar and three parts pitch oil, are heated in a tank of suitable capacity and design, until a temperature of between 350 deg. to 450 deg. F. is attained. If the temperature is allowed to fall below 350 deg. F. the preservative coating will be no better than mere tar, and if the temperature of the mixture exceeds

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* Based upon the formulæ specified by the late Dr. Angus Smith, and which he asked the writer to make public early in the eighties of last century.

450 deg. F. the pitch coating will be overheated and liable to scale off after application.

Having been heated to the proper temperature, the mixture is ready for the reception of the structural steel or iron members, which are then to be immersed in it, until they attain throughout their mass the same temperature as the mixture. The metal can then be gently lifted out of the preservative fluid by the aid of lifting tackle provided in conjunction with the tank, and which the author has designed to be portable so as to permit the process to be applied on the field of erection. The naphtha and other volatile oils evaporating will then leave a firm hard coating like pure pitch, which will tenaciously adhere to the steel surface, and being elastic, will expand and contract with the metal.

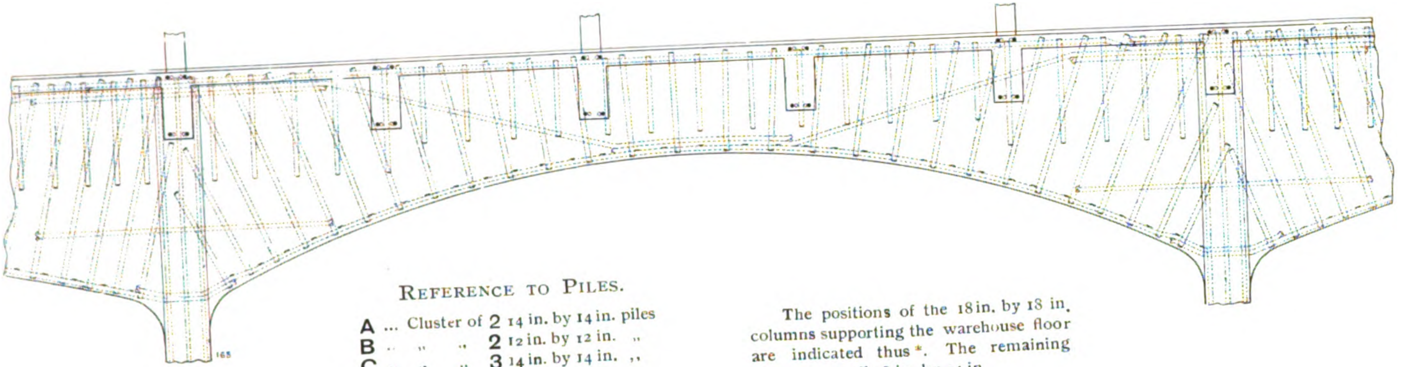
In the opinion of the writer, a hydro-carbonaceous coating of this kind is, next to cement, by far the best preservative yet put forward. It has been found to be an excellent preservative for water pipes, and if it is satisfactory for surfaces over which water is constantly flowing it should be much more so for static applications exposed to atmospheric influences only.

Any parts of the coating disturbed by riveting or other causes can be made more or less perfectly good by applying the hot fluid to the surfaces preliminarily heated by gas jets by heated iron plates, or in any other suitable manner. Rivet heads can be treated before they are allowed to cool, so that the erection disturbance of the Angus Smith coating can be effectively made good. As the hardening of the pitch surface does not depend on oxidisable driers there should be no pores through which the air can penetrate to the metallic surface.

Of course, when it is desired to ornament the metallic surfaces, ordinary paint of any colour can be applied to the pitched surfaces. For foundation steel elements, the application of the Angus Smith composition can, and should, be supplemented where practicable with a covering of Portland cement. These two effective preservatives should last for centuries, unless disturbed by violence.

CONCLUSION.

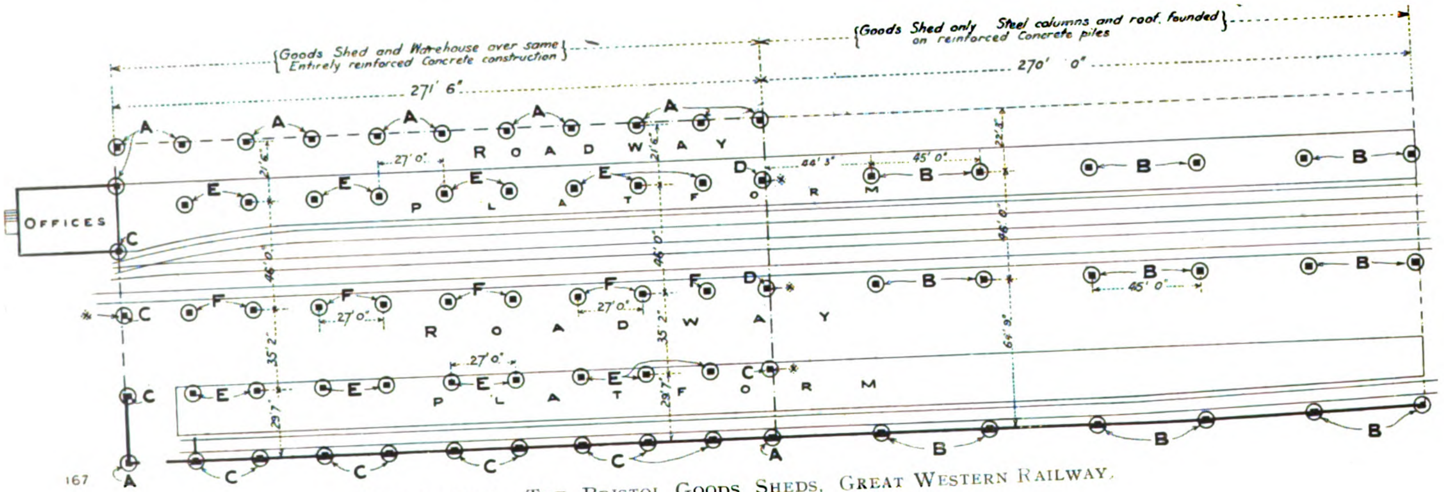
The author trusts that this discussion of the means available for the preservation of iron and steel employed in construction may be of some assistance to those who desire to adopt adequate methods of fighting against corrosion, and that it may also serve in some measure to allay the uneasiness recently expressed as to the permanence of future structures depending wholly or in part upon the continued strength of iron and steel members, if such members be suitably protected.



REFERENCE TO PILES.

A ...	Cluster of	2	14 in. by 14 in. piles
B ..	,, ,,	2	12 in. by 12 in. ,,
C ..	,, ,,	3	14 in. by 14 in. ,,
D ...	,, ,,	4	14 in. by 14 in. ,,
E ...	,, ,,	5	14 in. by 14 in. ,,
F ..	,, ,,	6	14 in. by 14 in. ,,

The positions of the 18 in. by 18 in. columns supporting the warehouse floor are indicated thus *. The remaining columns are all 18 in. by 24 in.


Goods Shed and Warehouse over same
Entirely reinforced Concrete construction
Goods Shed only Steel columns and roof founded on reinforced Concrete piles
271′ 6″
270′ 0″
OFFICES
ROADWAY
PLATFORM
ROADWAY
PLATFORM
A
B
C
D
E
F
27′ 0″
44′ 3″
45′ 0″
22′ 8″
21′ 6″
46′ 0″
35′ 2″
29′ 7″
64′ 9″
167

FIGS. 1 AND 4. THE BRISTOL GOODS SHEDS, GREAT WESTERN RAILWAY.

Reinforced Concrete on the Great Western Railway.

By W. ARMSTRONG, M.Inst.C.E.

(*Engineer for New Works, Great Western Railway*).

In no class of work does reinforced concrete perhaps lend itself so well as to the great structures of the Railway, Dock, and Canal Corporations, and we are glad to record that where there has been so much conservatism in the introduction of reinforced concrete, at least several of our great railway companies may be described as pioneers in its application. One of these companies is the Great Western Railway Company, and we herewith present, in the form of a special article, particulars of two of their more recent works.—ED.

THERE can be no question but that the use of reinforced concrete as a building material has made steady progress in England during the last few years, and particularly is this the case as applied to railway structures.

Our great railways have commenced to use reinforced concrete freely for general warehouses and office blocks, for wharves, cargo sheds, jetties, piers, quay retaining walls, and also for refuse destructors and coal hoppers, whilst many other uses are under immediate consideration.

So far, however, this new system of construction has not been utilised in England for the construction of railway bridges over which passenger trains would be run at high speeds, although it has been used, to a limited extent, for road bridges over railways. On the Continent, and in America, as is well known, there are many bridges constructed on this system over which passenger trains are run, so that the introduction of such bridges to British railway practice can only be a question of time.

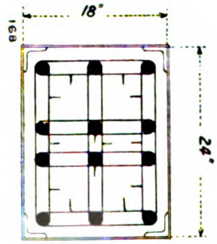


FIG. 3.

ADVANTAGES OF REINFORCED CONCRETE.

Before proceeding to describe any particular works on the railway with which I am associated, I would like to set out a few of the advantages of reinforced concrete that have come under my personal observation.

1. *Quickness in Construction.*—In reinforced concrete the varieties of materials required for the execution of the work are so few, so easily obtainable, and can be so

rapidly handled that structures as a rule, as far as my experience goes, are more quickly erected than is possible when brick or stone with steel are used.

2. *Cheapness.*—The cost of a brick or stone building in which steel is used, as compared with a reinforced concrete structure, has always been in favour of the latter, and this, I believe, is mainly the case by reason of the fact that the nature of the work does not call for the employment of much skilled labour. Good foremen are, of course, necessary, also carpenters for preparing the timber work, and smiths, but the bulk of the work can be carried out by unskilled labour. In the neighbourhood of London, where good Portland cement is apparently at its cheapest, and gravel and sand are readily obtainable, the comparatively low price of the necessary materials is specially advantageous to reinforced concrete.

3. *Adaptability for Bad Ground.*—It is in its adaptability for use in foundation work in bad ground, which is so frequently met with, that reinforced concrete, perhaps, has its chief claim to recognition in railway structures, and for this purpose experience has shown that it is far superior to the ordinary methods of construction, both from the point of view of cost and adaptability. For foundations in soft ground reinforced concrete is peculiarly adaptable, and this quite irrespective of whether the raft or the pile system be used. For pile foundations, piles may be safely placed 20 ft. or more apart, with reinforced concrete connecting girders or beams upon which the superstructure is to be erected, and where great loads are concentrated it is quite practicable to group piles and connect them together by means of a reinforced concrete platform, and so distribute the weight over a number of piles. This has been done in several instances where weights considerably in excess of 1,000 tons have been brought on such clusters of piles.

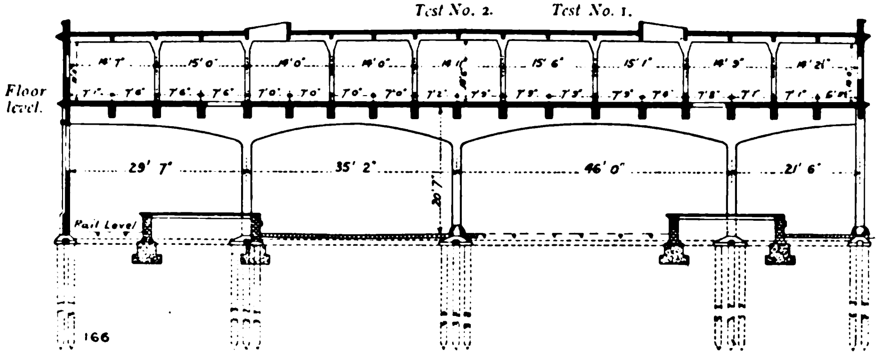


FIG. 2. THE BRISTOL GOODS SHEDS, GREAT WESTERN RAILWAY.

4. *Maintenance.*—It will be readily understood that the cost of maintenance on reinforced concrete is practically nil.

5. *Saving of space.*—By the use of reinforced concrete a valuable saving is effected in the thickness of the walls and floors, with a consequent increase in the space available for storage purposes and a decrease in the weight in the foundations, and particularly is this the case for floors designed to carry heavy loads.

If these five points alone be considered, the argument in favour of using reinforced concrete in railway work is a strong one, but there are additional advantages, such as that of fire resistance where suitable aggregates are used and the metal work is properly protected. Rigidity and absence of vibration are additional advantages.

EXAMPLES OF REINFORCED CONCRETE.

In order to demonstrate some of the uses to which reinforced concrete has been put on the Great Western Railway, I am presenting two characteristic examples, one at Bristol and one in London, in both of which the designs were prepared and the whole of the reinforced concrete work carried out on the "Hennebique" system, under the careful supervision of the railway's engineering department.

THE BRISTOL GOODS SHED.

At Bristol the new goods' shed, offices, and warehouse accommodation have just been completed. The goods' shed is 541 ft. long by 133 ft. wide, and the warehouse, which has a cubical capacity of 370,000 cubic feet, extends for 271 ft. of this length, but is of the full width; the height from ground line to top of parapet is 35 ft. A portion of the ground on which this structure has been erected was at one time a timber dock, and as thus little reliance could be placed in the ground, it was decided to drive reinforced concrete piles for the foundations. Further, from motives of economy and speed in construction, the portion of the structure over which the warehouse is built has been erected entirely in reinforced concrete, and it may be here stated that the warehouse floor, which has an area of 35,000 super feet, is designed to carry a load of 4 cwt. per super foot, and had to be tested up to 6 cwts. per super foot without showing any permanent deflection.

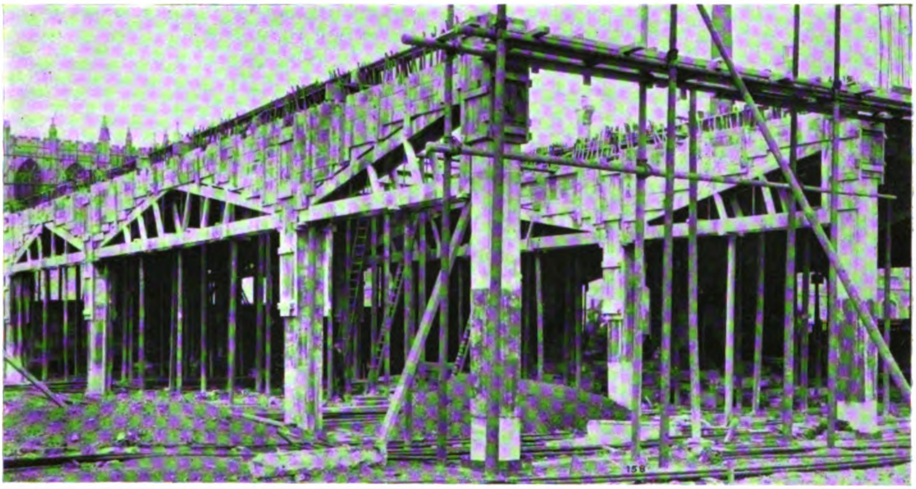


FIG. 5. THE BRISTOL GOODS SHEDS, GREAT WESTERN RAILWAY.

From *Fig.* 1 will be seen that the piles were driven in clusters of from two to six, the different piles being united 3 ft. below rail level by means of reinforced concrete slabs or bases; the clusters again being tied together by reinforced concrete beams. The number of piles driven to support the whole of the shed and offices, including that portion of the shed over which the warehouse does not extend, and the superstructure of which, with the exception of the flank wall, is built of steelwork, was 274, two sections being employed, viz., 14 in. by 14 in. for the portion over which the warehouse is constructed, and 12 in. by 12 in. for the remainder, consisting of the goods' shed only. The average length of the piles is 32 ft., and they were driven by means of a two-ton monkey with a drop of 4 ft., the blows being applied at the rate of about thirty per minute, a short and quick drop being preferred to a long and slow one.

A cross section (*Fig.* 2) through the building gives a good idea of the arrangement of the columns and main and secondary beams. In addition, it shows that the shed is traversed by four sidings and that two island platforms are provided at which goods can be dealt with by rail and road vehicles.

The goods shed may be said to be open on one side and at the two ends; at the other side a flank wall extending for the full length has been built, and in order to assist in carrying the floor of the warehouse above, it has been strengthened by the provision of piers 21 in. by 10 in., at 27 ft. centres, the panels between these piers being 7 in. thick up to a point 3 ft. 6 in. above ground level, then thinning to 6 in. In addition to the piers mentioned, the floor of the warehouse is supported by forty-two columns, the space from centre to centre of which is 27 ft. in the length of the structure, and the spans, reading from left to right of the cross section, are about 29 ft., 35 ft., 46 ft., and 21 ft. These columns, as well as the piers, are, of course founded on the piles previously described. Two sections have been employed, viz., 18 in. by 24 in., and 18 in. by 18 in. The latter are indicated on *Fig.* 1, all the remainder being 18 in. by 24 in. *Fig.* 3 is a section of a typical 18 in. by 24 in. column, the number and diameter of the steel bars used being governed by the weight to be brought on to the column. These bars are retained in position by the usual wire links and distance pieces at regular intervals. Up to plinth level the flank wall has been faced with blue bricks, and where the piers come this brickwork has been continued up to warehouse floor level. This was done for the sake of appearance only.

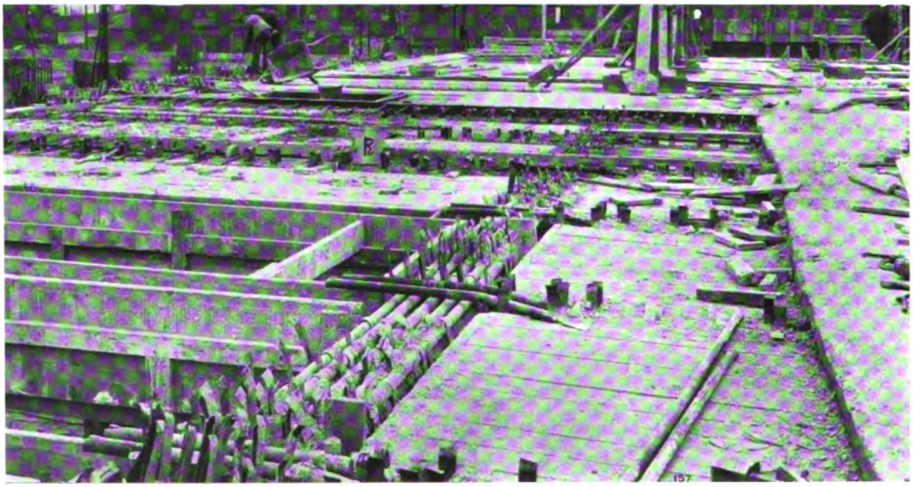


FIG. 6. THE BRISTOL GOODS SHEDS, GREAT WESTERN RAILWAY.

I have already stated the load the floor of the warehouse is designed to carry, and will now proceed to describe the girders, or main and secondary beams as they are called. The main beams, as will be observed from the cross section, are in form of elliptical arches of the spans before enumerated, and are 21 in. thick by 8 ft. deep at the springing and 3 ft. deep at the soffit, exclusive of the floor, the section being the same for the different spans. *Fig.* 4 shows the arrangement of the straight and trussed bars in these main beams, as well as the hoop iron stirrups, etc. *Fig.* 5 is from a photograph taken during the progress of the work, and shows the centering and shuttering for the moulding of the main beams.

The secondary beams were formed at the same time as the main beams, and are built into them so that they are part and parcel of each other and are jointless. They are at right angles to the main beams, spaced at varying distances, from 7 ft. to 7 ft. 9 in. centre to centre. In section they are 12 in. by 21 in. (deep) exclusive of the floor, which is 5½ in. thick and is strengthened by the addition of vertical steel bars. *Fig.* 6, also from a photograph, is a view of the warehouse floor, showing the method of forming the secondary beams and how they are built into the main beams.

The remainder of the work requires but little description. The walls of the warehouse are 7 in. thick, and the roof, which is nearly flat, only a sufficient fall being allowed for drainage purposes, is 3½ in. thick, and has been designed to carry a super load of 5 cwts. per super yard. The columns carrying the roof are 8 in. by 8 in. in section, 27 ft. apart centre to centre in the length of the building, and at centres varying from 14 ft. to 15 ft. 6 in. in the width.

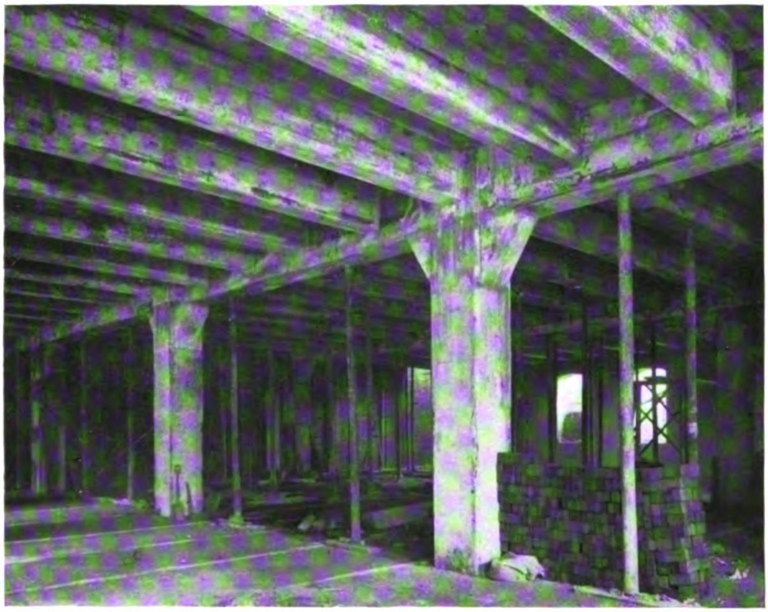


FIG. 7. THE STATIONERY STORE, ROYAL OAK STATION, GREAT WESTERN RAILWAY.

On page 109 a photograph is reproduced showing the structure complete except for the parapet, but the scaffolding had not been removed at the time.*

Regarding the concrete used, it comprised Pennant stone and granite chippings, the proportion of aggregate to cement being four to one for the columns and walls, and five to one for the beams and floors.

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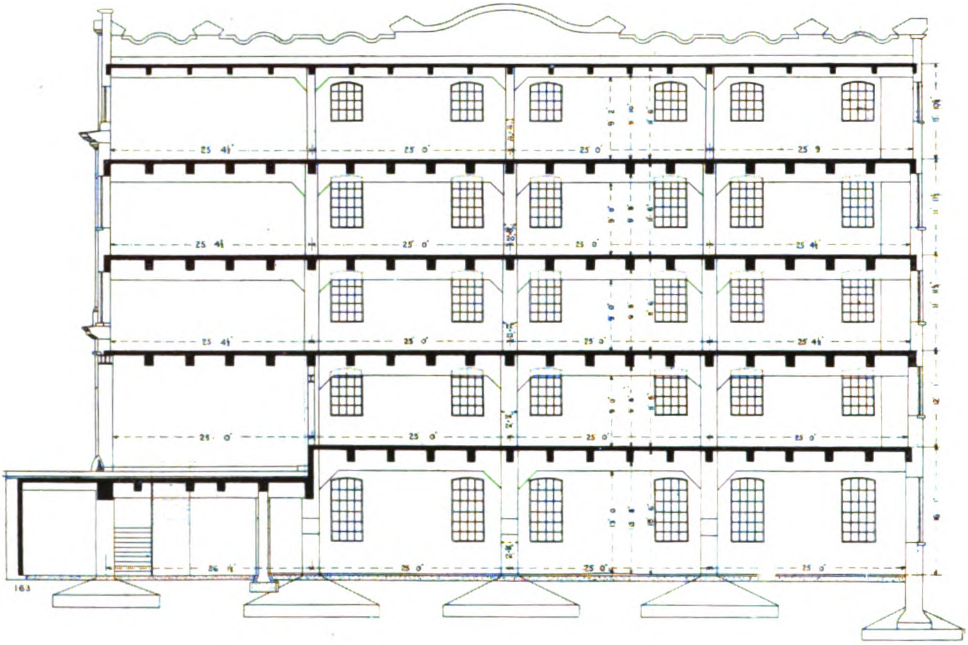
* The tests at Bristol took the form of two loading tests at floor level (see *Fig.* 2).

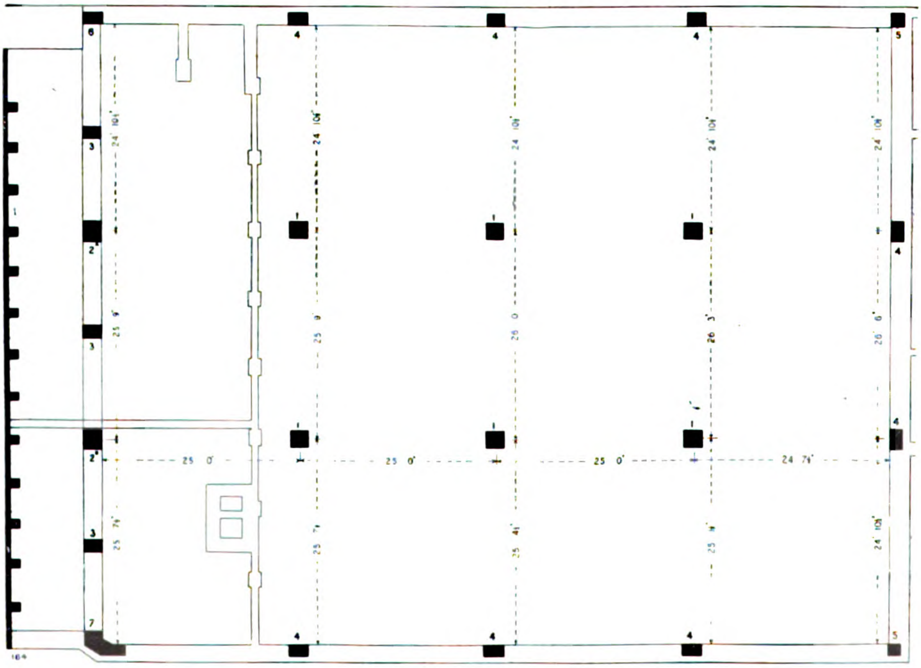
Test No. 1 was on a beam of 46 ft. span. The load was on a surface of 418·5 square feet for a normal load of 4 cwt. per square foot, with 50% excess = 125 tons 11 cwt. The deflection allowable was $\frac{\text{span}}{600} = \frac{59}{64}$ in.

The test occupied 11 days. When the max. load was applied on the 8th day, the max. deflection at centre was [illegible] in.

Test No. 2 was on a beam of 27 ft. span. The load was on a surface of 202·5 square feet (4 cwt. per square foot—50%)—60 tons 15 cwt. The allowable deflection was thus [illegible] in.

The test occupied 3 days. When the max. load was applied at the close of the first day, the max. deflection was [illegible] in.





FIGS. 8 AND 9 THE STATIONERY STORE, ROYAL OAK STATION, GREAT WESTERN RAILWAY. PLAN AND SECTION.

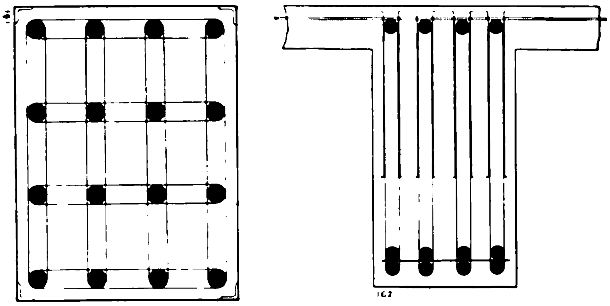
The average thickness of concrete on the columns outside steel framework is 1½ in. and under the floors 1 in.

STORES AT ROYAL OAK STATION, LONDON.

An interesting block of buildings now being constructed is the London Stationery Store at Royal Oak Station. This structure when completed will, to outward appearance, be constructed of red bricks, but, as a matter of fact, the skeleton framework and floors will be of reinforced concrete, and the framing will be put up independently on the American principle. An interior view taken during building operations is shown in *Fig. 7*.

The building in question, which will have a length of 104 ft. 6 in., and a breadth of 80 ft. 9 in. over all, will consist of a basement and four floors, with a height of 68 ft., from ground to top of parapet. The floors are to be put to the following uses: Basement—battery room in connection with electric sub-station and packing room and boiler house for heating apparatus; ground floor—offices and storage of stationery; first floor—ticket, printing, and bookbinding; and second and third floors—storage of books and papers.

From the description given it will be gathered that this structure will have to carry heavy loads; the foundation is in yellow clay, and eventually fast trains will be running within 5 ft. of the face of the building, so that it will be subject to constant vibration. For these reasons, coupled with the fact that it would be cheaper and quicker in construction than an ordinary building of brick walls and steel girders, a reinforced concrete erection with brick face walls was decided upon.



FIGS. 10 AND 11.

The accompanying diagram, *Fig.* 8, shows the general arrangement of the reinforced concrete columns which carry the whole weight of the floors from top to bottom. It will be seen from this that there are twenty main columns, the bases of which are so spread out that the calculated pressure on the ground under them will not exceed 3 tons per superficial foot of surface.

The spread of the foundations in the present instance has been designed to suit the nature of the soil, and the manner in which this has been done is indicated on the sketch section shown in *Fig.* 9, which also shows the general arrangement of the beams carrying the several floors, to which we shall refer later. The sizes of the columns are :—

No. 1	2 ft. 2 in. square.
No. 2a	2 ft. 4 in. square.
No. 2b	3 ft. 1 in. by 2 ft. 4 in.
No. 4	2 ft. 4 in. by 1 ft. 6 in.
No. 5	1 ft. 6 in. square.
No. 6	2 ft. 4 in. by 1 ft. 6 in.
No. 7 ... Is	of irregular shape to suit the splayed angle of the building, but has a sectional area of 10½ square feet.

In addition there are three subsidiary columns in the basement, No. 3—2 ft. 4 in. by 1 ft. 2 in., but these only assist to sustain the main beams on which the front wall of the building is built. It will, of course, be understood that the sizes given are those in the basement, and that as the building rises the sectional area of each is diminished by reason of the less work it has to perform. The sizes of the columns on the various floors are indicated on *Fig.* 9

The number and arrangement of the iron rods in the columns varies according to the weight they are calculated to carry, but in *Fig.* 10 is shown a section of a typical column which indicates the method in which the rods are held in position by wire links provided at regular intervals, and also shows that the corners of the columns are protected from damage by trolleys, etc., by round-backed angle irons, which extend to a height of about 6 ft. above floor level.

Cellarage accommodation extends under the public footpath for the extent of the street frontage, and the ground has been held up by the provision of a reinforced concrete retaining wall only 6 in. thick, but with piers 12 in. square at 5 ft. centres.

The front wall of the building is carried by the reinforced concrete beams. previously referred to, whilst the remaining walls are carried on slabs of reinforced concrete 5 ft. wide and 9 in. thick, joined into the bases of the columns.

The floors are to be constructed to carry a safe load of 5 cwt. per super foot, and on completion a test load of 7½ cwt. per super foot will be applied, which the floor must stand without showing any permanent deflection. In the first place it should be stated that the clear span of the main beams, which run from front to back of the building, is about 23 ft. between the columns. Incorporated into these main beams and at right angles to them are smaller or secondary beams for the width of the building, with a clear span of about 24 ft. at about 5 ft. centres, and which in their turn carry the floor.

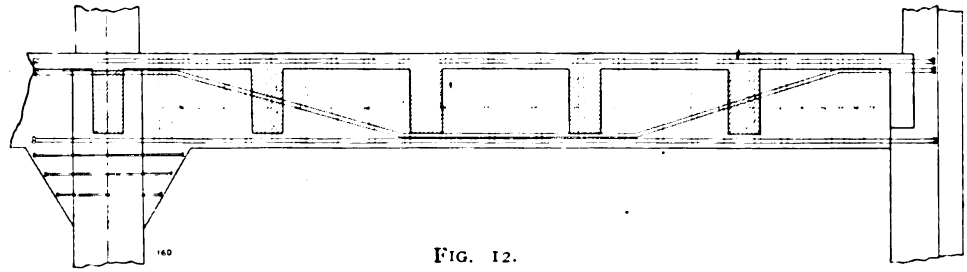


FIG. 12.

The main beams are generally 18 in. thick by 30 in. deep, exclusive of the floor and *Fig.* 11 gives a section of a typical beam, showing the general arrangement of the iron rods and the hoop iron stirrups, which hold the rods in position. *Fig.* 12 is a sectional elevation of a main beam, indicating that some of the rods are straight and others trussed, and also showing that the columns and main and secondary beams, where they join one another, are formed at one and the same time, so that the result is a homogeneous whole, there being absolutely no joint

The secondary beams are mainly 12 in. thick by 22 in. deep, also exclusive of the thickness of the floor, and apart from their sectional area and the number of rods running through them, the general arrangement is much the same as for the main beams.

The floor is 5½ in. thick, and the area of flooring carried by each secondary beam will be approximately 125 super feet.

The roof is of lighter construction than the floors beneath, and, being flat, could, if necessary, be utilised for the stacking of materials not liable to damage by the weather. It is capable of carrying a load of 5 cwt. per square yard.

Regarding the concrete used, it comprised Thames ballast broken to ¾ in. maximum, the proportions of aggregate to cement being five to one. The thickness of the concrete protecting the steel is as at Bristol.

FOUNDATIONS.

Reverting to the Bristol example, where reinforced concrete piles were used, doubts have often been expressed as to the protective covering of concrete being sufficiently impermeable to prevent water getting access to the rods and setting up oxidation. That it is impermeable, provided that the materials used are of the best, was proved beyond question a short time ago when the writer was present at the breaking up of the head of a reinforced concrete pile, constructed on the Hennebique system, that had been left lying in the mud on the foreshore for about seven years, during which time it was exposed and covered daily by the turns of the tide. On that occasion it was observed that, although the rods projecting at either end were much oxidised, the sea-water had had absolutely no effect on them where they were protected by the covering of concrete, even where such covering was only ⅛ in. thick. This section of pile had not been specially prepared for testing, but as a matter of fact was an end cut off a pile.

That the reinforced concrete piles are not only desirable in soft ground or for sea work, but are also of considerable value under other conditions, the following instances will show. Some six years ago a grain warehouse of two stories was constructed of reinforced concrete at Plymouth Docks, the structure having a frontage of 70 ft. to a maximum depth of 80 ft. Difficulty was expected with the foundations, inasmuch as the shed was to be built on made ground, the filling, however, instead of being of soft material, consisting of limestone quarry refuse, extending at the deepest part to a depth of 36 ft., and out of which all the soft material had been washed by the action of the water. A test timber pile, driven to ascertain, if possible, the depth to which the concrete piles would have to be driven before getting on to rock, could not be driven further than 10 ft. On the other hand, the reinforced concrete piles of lengths varying from 12 ft. to 40 ft. were rammed home most successfully. The concrete piles used were 14 in. square, with 1⅛ in. round rods, and the concrete used was of one part Portland cement to 4½ parts washed sand and Bideford gravel (⅜ in. mesh), machine mixed. The monkey used was 30 cwt., and the usual protection of sawdust, steel head, and wooden dolly, afforded during the ramming, driving being stopped if ten blows of 8 ft. drop did not obtain ⅛ in. penetration.

CONCLUSION.

With such examples as these to go upon, the advantages of the reinforced concrete—both above ground and below—cannot but soon lead to its more general introduction in railway work.

Hollow Concrete Block Building Construction in the United States.

By S. B. NEWBERRY,
Cleveland, U.S.A.

A PAPER

read before

THE ASSOCIATION OF AMERICAN PORTLAND CEMENT MANUFACTURERS.

The increasing popularity of hollow concrete blocks for domestic buildings in the United States calls for serious attention in the British Isles, and more particularly in those districts where the primary constituents of the hollow block, namely, Portland cement and sand, are obtainable at a moderate figure. The paper presented by the author should serve as an excellent argument in favour of the adoption of such blocks in building practice. The Cheap Cottages Exhibition of last year clearly demonstrated that there was nothing to fear on the artistic side from hollow concrete blocks. The practical advantages are obvious.—ED.

WITHIN the past five years a new building material, the hollow concrete block, has come rapidly into use, and the industry has grown almost as surprisingly as the manufacture of Portland cement. Concrete building blocks were practically unknown in 1900, but it is probably safe to say that at present more than a thousand companies and individuals are engaged in their manufacture in the United States.

The cause of this remarkable development of a new material of construction is chiefly to be found in the rapidly failing supply of lumber, together with the widespread public interest in all applications of Portland cement. The advance of more than 50 per cent. in the price of lumber during the past few years has been a serious hardship and obstacle to the increasing multitude of people who aspire to having homes of their own, and it is but natural that builders should look about for some efficient substitute for wood, and should look with favour on a material which offers advantage of durability, safety, comfort, and beauty which are unknown in frame construction.

There is good reason to believe that this efficient substitute for wood has been found in the hollow concrete block, and that we are still only on the threshold of the development of this building material. Opposition to its use on the part of the consumer is not to be feared; the obstacles to be overcome lie chiefly in the danger of careless or ignorant work by block-makers and builders, and in the need of study and invention to adapt the material to the economical production of convenient and beautiful structures. There is every reason why concrete should become the chief building material of the future. For large and costly buildings it is likely that solid concrete, plain or reinforced, will have the preference. For smaller structures, especially factories and dwellings, hollow blocks are certainly cheaper, more suitable, and require much less technical skill in erection. The possibilities of this type of construction seem to be unlimited. Those who realise what *may* be done in this direction can hardly resist a feeling of impatience at the comparatively crude and clumsy work which has thus far generally been accomplished. All that is needed to secure an immense expansion of the concrete block industry is to improve the design of machines and product so as to make block construction simple, practical and beautiful. To accomplish this, ingenuity, invention and good taste will be required, and there is little doubt that these qualities, so characteristic of the American people, will in abundant measure be brought to bear upon the problem. The following suggestions on concrete blocks and their manufacture, by one who has had several years' experience in the business, are offered in the hope of contributing, to a slight extent, towards the progress which all who have faith in cement must have at heart.

HISTORICAL.

The use of concrete for building construction dates back to the time of the Romans. Though their only cement was a mixture of volcanic scoria with slaked lime, they showed a degree of skill and boldness in the moulding of walls, arches and domes which is scarcely equalled at the present day, and many of their structures will stand as striking examples of the everlasting qualities of artificial stone.

The moulding of concrete into separate blocks, to be used for building in the same manner as brick or blocks of stone, appears first to have been introduced in the early part of the nineteenth century. Solid blocks were first made, but proved heavy to handle and found but scanty use. Hollow blocks, to be used as such or filled up with concrete after placing in the walls, were patented by Sellars, in England, in 1875. Concrete facing slabs, with projections to secure them to the concrete filling, soon followed, and in 1878 Lish, of Newcastle, patented a very ingenious Z-shaped block, by the suitable placing of which hollow walls were produced.* All accounts indicate that these blocks were made by pouring wet concrete, allowed to harden many hours before removing the moulds, a somewhat costly and tedious process.

MATERIALS.

Portland cement, owing to its uniformity, strength, and especially its promptness in hardening, is the only hydraulic material which finds any considerable use in block-making. A great point in favour of Portland cement is that it gains at least as great strength in air as in water, other hydraulic cements are generally unsuitable for work not kept permanently wet. At the present moderate price of Portland cement it is certainly cheaper in use, for a given strength, than any of its substitutes.

The " aggregate," or inert coarse material used with cement to produce concrete for blocks, may be either sand and gravel or stone screenings. There is little choice between these two classes of material, if of good quality. Sand and gravel are generally cheaper, and are usually somewhat easier to perfectly mix with the cement. In the matter of strength and hardness of the resulting blocks there appears to be little or no difference.

The strength of concrete depends greatly on the density of the mixture, and this is chiefly a question of voids in the aggregate used. It is well known that a mixture of cement and sand is weaker than the same mixture with the addition of coarse gravel. For example, a mixture of cement 1, sand 3, will show a lower strength than cement 1, sand 3, and gravel 4, though the latter mixture contains only half as much cement as the former. This is due to the reduction of the voids in the mass by the addition of coarse gravel.

As an example of this , the writer made the following experiments on two samples of gravel :—

	Wt. Per Cu. Ft.	% Voids.
No. 1, sand and fine gravel	127·5 lb.	2·29
No. 2, coarse gravel, nut to egg size	100·9 lb.	38·9
Nos. 1 and 2, mixed, equal weights	139·6 lb.	15·5

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* See Potter, " Concrete, Its Use in Building." Winchester, 1891.

Note the surprising increase in density on adding the coarse gravel. A concrete of cement with 6 parts of Nos. 1 and 2 mixed would undoubtedly have shown as great strength as 1 of cement to 3½ parts of No. 1 alone.

A good indication of the value of gravel or stone screenings for concrete may be obtained by filling a cubic foot box with the material and weighing it. A solid block of one cubic foot of limestone or quartz, free from voids, would weigh 165 lb. The amount by which a cubic foot of gravel or stone falls short of this weight represents the proportion of voids, or empty spaces, contained in it. For example, if a cubic foot of gravel weighs 130 lb., the voids would be 35–165 of the total volume, or 21·2 per cent. A few trials will show that for best results the mixture must contain *a large proportion of coarse material.* Very few gravels will be found that are not improved by the addition of pebbles, and the greatest strength is obtained with material that contains comparatively little sand.

There is, however, another consideration which enters into the selection of materials for block-concrete, and that is the appearance of the surface of the work. Unless a facing is used, a fair amount of fine material must be present to give the blocks an even surface. Nevertheless, it will be found that much coarser gravel or screenings may be used, with good results, than is generally supposed, and that the appearance of the work is not injured by the addition of a large proportion of coarse pebbles, up to about ¾ in., while the strength and density are greatly improved by this addition. A 1 to 5 mixture of cement and gravel, containing at least 50 per cent. of pebbles remaining on an ⅛ in. screen, will be found better than a 1 to 3 mixture of cement and sand only.

As to the character of the sand and gravel to be used, there are many tests on record which show that rounded grains give greater density and strength than sharp irregular splinters, and that a small percentage of loam or clay does no harm providing the mixing with cement is thoroughly done.

Another material which may be used with advantage in block-concrete is *slaked lime.* In poor mixtures, as 1 to 4 and 1 to 5, the addition of lime improves the strength and lessens penetration of water ; it also makes the blocks whiter on drying. It is, possible, also, to replace part of the cement used, perhaps one-third, by slaked lime without loss of strength. The most convenient form of lime for block-makers' use is the dry-slaked or " hydrate " lime, now a common article of commerce. At present prices, hydrate lime costs almost as much as Portland cement, and there is no great saving in using it. However, it forms a simple means of improving the appearance and water-resisting qualities of the work, and a few experiments will convince most block-makers that it is a valuable addition to the mixture.

PROPORTIONS.

Cement.—The proportion of cement to be used will depend on the strength appearance and impermeability desired. So far as strength is concerned, very poor mixtures, as 1 to 7 or 8, may answer every requirement. Blocks made from such poor mixtures, however, absorb water like a sponge, and will not answer for the walls of dwellings, though they may perhaps be good enough for partitions, retaining walls and buildings in which dampness is no objection. For dwellings, a poorer mixture than 1 to 5 is not to be recommended. Much depends, of course, on the character of the gravel or screenings employed. With properly graded gravel or screenings, containing a large proportion of coarse material, a 1 to 5 mixture will be found better than 1 to 3 with cement and sand only. The writer would recommend a mixture composed as follows, by measure : Cement 1, hydrate lime ½, sand and gravel 6.

This is practically a 1 to 4 mixture, and will be found to possess fair waterproof qualities, sufficient at least for dwellings which are to be furred and lathed. If plastering is to be applied directly to the inside surface of the walls, it is necessary that the blocks shall absorb water only very slowly, so as to be only partially penetrated during a long-continued rain. Such a result can be reached by giving the blocks a facing of richer material, perhaps 1 to 2, or by using a sufficiently rich mixture for the whole body of the blocks, such as: Cement 1½, hydrate lime ½, sand and gravel 5; or, cement 1, hydrate lime 1, sand and gravel 5.

These should be effective with gravel or screenings of suitable character. The block-maker should experiment with the materials at his disposal, and thus ascertain what proportions are suitable for the special purposes he may have in view.

Another method of producing watertight blocks, which is effective with mixtures as poor as 1 to 6, is by the use of a special waterproof compound, invented by the writer, particulars of which will be furnished on application.

Water.—The use of a proper amount of water is essential to good work, and in this respect many block-makers are extremely careless. It is well known that a fairly wet concrete is far better than a dry one, and that too much water is better than too little. A rather dry mixture may be more convenient to use, and may enable the maker to turn out a larger number of blocks in a day, but the resulting work will always be porous, weak and crumbling. On the other hand, the extravagant claims made for the wet process, in which the concrete is poured into the moulds and left for many hours to harden, are, according to the writer's experience, chiefly imaginary. It is perfectly practical to produce concrete of the highest possible quality, and still to remove the blocks at once from the moulds. The mixture must be *as wet as it can be made without sticking to the plates*, and without sagging or becoming distorted when taken from the machine. Blocks so made will be found at least equal in strength and hardness to any that can be made by pouring. They are also much more attractive in appearance, showing a rich, sandstone-like surface, instead of the dull, lifeless look which the wet process gives. As compared with blocks made from too dry a mixture, they are lighter in colour, denser, stronger and more impermeable.

The correct percentage of water varies with the materials, but is generally from 8 to 9 per cent. of the mixture by weight. It will be found that a mixture containing much coarse gravel or stone may be made much wetter, without sagging or sticking, than one of finer material.

MANUFACTURE.

Mixing.—The materials, carefully measured, should be thoroughly mixed dry, then the proper amount of water added, and the mixing continued. Thoroughness in this part of the operation will be found to pay for itself many times in improved work. Uneven colour of blocks results from imperfect mixing, and especially from varying the proportion of water. Use of a good concrete-mixer is far preferable to mixing by hand, both in saving of time and labour, and in thoroughness of work done. Hand mixing, by the use of a hoe, must be vigorous and long-continued, or the full effect of the cement used will not be obtained. The inferior work of many small-scale block-makers is largely due to this cause.

For the preparation of concrete for blocks, in which thorough mixing and use of an exact and uniform proportion of water are necessary, *continuous* mixing machines are unsuitable, and *batch mixers*, in which a measured batch of the materials is mixed the required time and then discharged, are the only type which will be found effective. The writer prefers a batch mixer of the intermittent pugmill type, with hinged bottom discharge, as made by the Drake Concrete Machinery Company, of Chicago. If such a machine is purchased, extensible mixing arms of chilled iron, capable of being lengthened as the ends become worn, should be insisted upon. Another machine which the writer has seen in successful use is the revolving pan mixer with central discharge, made by the Elliott and Walker Co., Wilmington, Del.

Block Machines.—There are a multitude of machines on the market, and new advertisements appear in every issue of the cement journals. From this we may well believe that money is more easily made by the sale of machines than by their use in block manufacture. Practically all the machines offered are repetitions of the same fundamental design, and differ only in minor mechanical details. A discussion of relative merits and expression of preference would be useless. Each intending purchaser should study the various machines offered and select that best adapted to his needs, giving preference to those of solid and substantial construction, and taking care that he gets real value rather than " blue sky " for his good money.

Block machines may be generally divided into two groups: those with horizontal and vertical cores. The former are usually considered the more convenient for making " faced " blocks, though a facing can be put on with either type of machine. The use of a facing of finer, richer or coloured mixture must be called a matter of taste. In the judgment of the writer, it does not pay to use a facing, as the additional labour and preparation of a separate mixture cost more than to make the whole block of suitable composition, to give a good surface. If the fancy differs much from the body in composition, also, it is likely not to adhere perfectly, and trouble has been experienced from this cause. However, for waterproof and coloured work, a facing may be found an advantage, and doubtless many will give preference to a machine which allows this to be conveniently applied.

Machines are provided with face-plates for the production of rock-faced, tool-faced and plain blocks, and various ornamental designs, for borders and friezes, are also furnished. Plates for rock-faced blocks should always be cast from a *natural stone*, and several different patterns of each size should be obtained, to avoid monotony in appearance of the work. Many machines are provided with rock-face plates evidently cast from some moulded soft material, which yield blocks with a surface more like that of pats of butter than natural stone. Such makeshifts are abominable, and a fraud on the purchaser.

As to the size of blocks, most machine-makers appear to have adopted the standard dimensions of 32 in. in length by 9 in. in height, giving 2 square feet of face to each block. Machines are generally made for blocks, 8, 10 or 12 in. in thickness. Some machines are adjustable to allow blocks of either thickness to be made. Where the business will warrant it, however, it saves time to have a machine for each size. An 8-in. wall is abundantly strong for foundations or walls of two-storey dwellings, but in many cities the building code prohibits anything less than 12-in. walls for foundation and first storey. There seems to be only small demand for the 10-in. block.

Machines are generally provided with attachments for making corner blocks. Arrangements for making 45-deg. and 30-deg. angle blocks for bays and towers are also desirable.

Tamping.—This is generally done by hand, by means of iron rammers. Some well-equipped plants use pneumatic tampers, operated by compressed air, with considerable economy in labour and probably some improvement in density. Excellent results can, however, be obtained by hand-tamping, if the mixture is wet enough.

Sticking to the plates may be largely prevented by rubbing the inside surface, when dry, with paraffin, animal or vegetable oil, or soft soap. Mineral oils, such as common lubricating oil, are less effective.

Handling, Hardening and Storage.—For good results, blocks must be kept under roof, protected from sun and wind, and frequently sprinkled, for at least five days, and preferably for seven days. They may then be piled up outside, and in dry weather should be kept moist by occasional sprinkling with hose for at least three weeks more. Blocks should never be built into a wall until at least four weeks old. Freshly made blocks will be found to shrink more than $\frac{1}{16}$-in. in length on seasoning a month, and if put into a building when only a few days old will develop unsightly cracks in the joints or through the blocks themselves.

In handling blocks from the machines the use of three-decked cars on tracks will be found a great saving in time and labour. In a factory so equipped, each machine, with two men tamping and one shovelling, will easily make 150 blocks, 32 in. long and 8 in. wide, in ten hours.

PROPERTIES OF BLOCKS.

Strength.—Well-made Portland cement concrete, of good sand and gravel or limestone screenings, 1 to 5, will have a compression strength at four weeks of over 2,000 lb. per square inch, and at one year of over 3,000 lb. Tests of various mixtures, in 3-in. cubes, at the Case School of Science, in Cleveland, showed the following :—

COMPRESSION STRENGTH AT SIX WEEKS.

		Strength lbs. per sq. In.	Specific Gravity.	Water Absorption %
Cement Sand and Gravel,	1½ 6	3,200	2·17	4·16
Cement, Hydrate Lime, Sand and Gravel,	1½ ½ 6	3,880	2·18	4·10
Cement, Limestone Screenings, (Poured in porous mold)	1½ 6	2,000	2·05	5·04

It is very difficult to obtain reliable crushing tests of casual hollow blocks, owing to the difficulty of applying the load uniformly over the whole surface. Three one-quarter blocks, 8 in. long, 8 in. wide, and 9 in. high, ten weeks old, made of cement 1½, lime ½, sand and gravel 6, were crushed with the following results :—

	Net Area.	Max. Load.	Stress Per Sq. In.
No. 1.	49·7 sq. in.	99,700 lb.	2,000 lb.
No. 2.	49·7 sq. in.	89,800 lb.	1,805 lb.
No. 3.	49·7 sq. in.	76,200 lb.	1,530 lb

Two blocks, 6 by 8 by 9 in., twenty-two months old, showed a crushing strength of 2,530 and 2,610 lb. per square inch.

Now a block 8 in. wide and 32 in. long weighs 120 lb., and has a surface of 174 square inches. Assuming a crushing strength of 2,000 lb. per square inch, we find by calculation that 2,900 blocks could be piled one upon another before the lowest would give way, making a total height of 2,175 ft. Allowing a factor of safety of 5, a height of 435 ft. would be admissible. This shows how greatly the strength of concrete blocks exceeds any demands which could possibly be made upon them. As stated above, if it were not for the question of water absorption, much poorer mixtures than are generally used would give abundant strength. Where waterproof qualities are no object, and good gravel, containing plenty of coarse pebbles is to be had, mixtures as poor as 1 to 8, or 1 to 10, will often be found to answer. The following table of tests of various mixtures, made by the writer, shows the good results that can be obtained with low proportions of cement, especially with the addition of hydrate lime. It should be remembered that the compression strength of concrete is generally about ten times its tensile strength. The water absorption given is the per cent. of water, by weight, which the dry block absorbed after soaking twenty-four hours. The tensile strengths are the average of four briquettes each. The sand used was a coarse bank sand, containing very little gravel. The cost of material is based on assumed price of $1.50 (6s.) per barrel for cement, $5 (£1) per ton for hydrate lime, and 25 cents (1s.) per ton for sand, and is stated in cents per 8 in. block, 32 in. long.

Proportions by Weight.	Tensile Strength 22 Days.	Wt. per Cu. Ft. lb.	Water Absorption.	Cost Materials for 8 in. Blooks.
Cement 150, hyd. lime 0, sand 600 ..	334	130·0	7·72	11·2c*(5½d.)
,, 125, ,, ,, 25, ,, 600 ..	360	136·4	5·75	10·6c (5d.)
,, 100, ,, ,, 50, ,, 600 ..	278	139·5	5·23	10·0c (5d.)
,, 100, ,, ,, 25, , 600 ..	197	136·0	5·75	9·0c (4½d.)
,, 50, ,, ,, 50, ,, 600 ..	182	132·6	7·03	6·7c (3½d.)

Approximate equivalents in pence.

It will be noted that the hydrate lime considerably decreases the water absorption and in small proportions increases the strength. The last mixture, 1 to 1 to 12, appears strong enough for all practical purposes, and is actually less permeable than the first, consisting of cement and sand, 1 to 4, without lime. It is evident that in the vast sections of our country in which sand and gravel are to be had, almost without cost, in unlimited quantities concrete blocks made from such a mixture would be far cheaper than lumber, and ought easily to replace all other building materials. All that is needed to bring this about is practical demonstration, and the requisite skill and ingenuity on the part of architects and builders. It is conceivable that a type of construction for small dwellings, using a 4 in. or 5-in. hollow block, might easily be developed, and these could be turned out, two at a time, on 8-in. or 10-in. machines, provided with suitable cores and partition. The possibilities of development in this direction seem almost limitless.

WATER ABSORPTION.

One of the chief faults often observed in work done with concrete blocks is their tendency to absorb water to such an extent as to cause dampness to appear on the interior surface. This is especially noticeable in blocks poor in cement and made to dry. The fault may be overcome by use of suitable materials and sufficient care in manufacture.

The terms " porosity " and " permeability " are often used, and by many supposed to be of the same meaning. The porosity of concrete is, however, the proportion of voids, or empty spaces, which it contains, while the permeability is the rate of speed with which water, under a certain pressure, will pass through it. All concretes and mortars are more or less porous, and all are somewhat permeable by water under heavy pressure. It is well known that, with the same proportions of cement, mixtures of fine sand are more porous than those of coarse sand. The latter are, however, much more permeable than the former. Feret has shown that the porosity is the total amount of voids contained in the mass, while the permeability depends on the size of the individual openings. The least porous concrete may, therefore, be the most permeable, and *vice versa*. If, however, both fine and coarse grains are present in proper proportion, the mass will show the least porosity and at the same time be the least permeable. The concrete which best resists water will therefore be that which is most dense, provided a sufficient amount of fine grains are present.

If a concrete block be immersed in water it will gradually absorb the liquid, and in time the amount of water taken up will be nearly equal to the total of voids present. The rapidity with which this absorption takes place will differ greatly, however, with different mixtures of the same porosity; blocks containing fine material in the right proportion will be found to absorb water much more slowly than those made from coarse materials only. It is the *speed* with which the water is absorbed that is of consequence in the case of concrete blocks, rather than the total amount which will be taken up after a long time. If the absorption is slow the moisture during a long-continued rain will penetrate only partially through the block, and will dry out again before the surface is again wetted. Perfectly waterproof walls are not necessary, and are even objectionable, owing to their tendency to "sweat" from the deposition of moisture on the inside surface. For health and dryness it is necessary that a gradual circulation of air through the walls should take place, and that any moisture condensing on the inside shall be absorbed and carried away.

Sufficient impermeability for practical purposes, to avoid all danger of dampness penetrating from the outside may be secured by use of (*a*) sufficiently large proportion of cement, (*b*) addition of hydrate lime, and (*c*) suitable sand and gravel or screenings, containing both fine and coarse material.

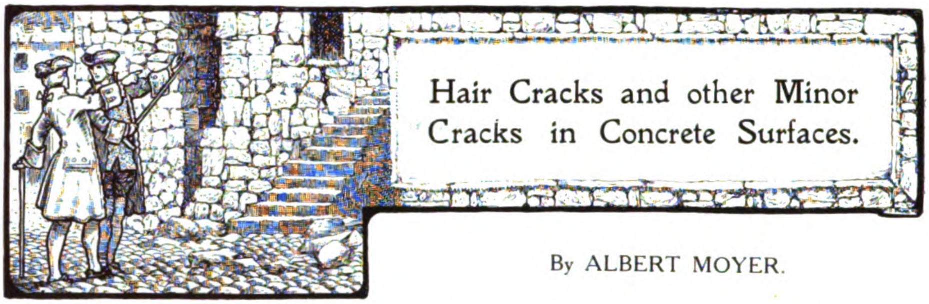
With poorer mixtures, which would otherwise be too absorbent for use in the walls of dwellings, any desired waterproof qualities may be secured by the addition of a very small percentage of waterproof compound, as already explained.

COLOUR.

The experience of the writer has been that the natural stone colour, obtained by the use of ordinary sand and gravel or screenings, is more popular with purchasers of blocks than any tint which may be given by addition of pigments to the mixture. Limestone screenings give a lighter colour than most kinds of sand, but the colour is chiefly determined by the cement used, and the tint obtained with white sand is very little lighter than that with sand of ordinary grey shade. The addition of hydrate lime makes the blocks decidedly lighter in colour, and the same result is obtained in still greater degree, by making the mixture as wet as possible. The difference between blocks made fairly wet and those made too dry will be found to be very striking.

Coloured blocks, imitating various tints of natural stone, may be obtained by a facing of richer mixture to which from 1 to 3 per cent. of dry mineral colour has been added. The colours most suitable are (*a*) Red iron ore paint or Venetian red; (*b*) Yellow ochre; (*c*) Ultramarine blue, and (*d*) Ultramarine green.

These colours are inexpensive, and may be mixed to any desired shade. It must be remembered that all cement work bleaches and whitens decidedly on hardening and drying. The colour of the freshly-made blocks must therefore be much deeper than it will appear after a few weeks exposure to weather. Deep and strong colours are, in fact, difficult to secure in cement work.



Hair Cracks and other Minor Cracks in Concrete Surfaces.

By ALBERT MOYER.

Cracks in concrete work are always the cause of considerable anxiety to the designer and contractor alike. No matter how slight the crack, it is almost invariably a source of irritation to the building owner. The nature of cracks arising from other causes than those of settlements, require greater attention than has so far been accorded them. For this reason we present an article on this somewhat neglected subject.—ED.

THE appearance of hair cracks on a concrete surface is a disfigurement, the cause and remedy for which have not received the proper study that so important a subject justifies. The cause of this trouble has been investigated from time to time, but heretofore the conclusions drawn have been very incomplete.

Hair cracks, being entirely on the surface, do not indicate a weakness in the concrete ; in most instances they are not greater in depth or width than that of a coarse hair. A rough-surface concrete does not display these objectionable features to as great an extent as does an even-trowelled face, on which surface they are very apparent, especially in damp or wet weather. Often these cracks do not appear for several weeks or months after the concrete has set hard.

A practical worker in concrete is not as much concerned with the cause of hair cracks and crazing as he is interested in their effect and remedy. It often requires investigation as to cause to arrive at a correct solution of the trouble and thus apply permanent remedy, otherwise we would be simply dealing with symptoms. Research conducted along theoretical lines seldom brings practical results, therefore the writer will endeavour to eliminate theory as far as possible. His investigation has been founded on the reverse practice ; that of noting and observing very carefully the practical results both as to effect and remedy, and then endeavouring to explain these conclusions by theory.

SO-CALLED "CRAZING."

It has been known for some time that very wet concrete is more apt to craze and show these undesirable hair cracks than dry concrete. Dry concrete is objectionable from the standpoint of strength and density ; and, therefore, its use cannot be advocated simply because hair cracks are to some extent avoided. Investigation and practical demonstration leave no doubt of the fact that in wet concrete a portion of the flour or very finest particles of the cement is carried to the surface by the action of the excess water which is being absorbed by the atmosphere. This excess water is to a great extent drawn from the interior of the stone to the exterior, carrying with it the finer particles, which, being deposited on the surface, form a richer mortar than is contained in the body of the concrete. Under certain conditions these fine particles deposited on the surface practically form a coating of neat cement.

Neat cement or the richer mortars are found to be much more liable to crazing than mortars containing a larger proportion of sand or finely crushed stone. This is particularly true in the manufacture of cement stone by the use of sand moulds in which the mixture is poured very wet. It has also been noted that, when the stone is properly seasoned by keeping the surface covered with a thick layer of very wet sand, or when the stone is immersed entirely and for some time in water, the trouble has been overcome almost entirely. These hair or map cracks would be entirely eliminated for all time if the stone were immersed in water for a sufficient period to allow the complete crystallisation of the cement. This, however, is not always permitted by convenience or economy.

The crazing of neat cement is apparent in test pats for laboratory purposes, when these pats are exposed and allowed to set and harden in air, but if they are protected in a moist closet and afterwards immersed in water for a period of at least 28 days, no hair cracks or crazing will result.

A careful examination of these cracks led to the conclusion that they are due entirely to a contraction of the surface, the same contraction not taking place in the body of the concrete.

SOME EXPERIMENTS.

Experiments made by Prof. Swain and Prof. Bauschinger demonstrate that neat cement contracts when set and hardened in air. This applies to all brands of high grade Portland cement. Further tests demonstrate that this contraction increases with age up to a certain period. The same authorities demonstrate that a mortar made of one part Portland cement and three parts sand, hardened in air, shows contraction, but less in proportion than the neat cement. It is obvious that this bears out the practical investigations regarding concrete and cement stone which have been described above; that is, hair cracks are due to contraction of the surface, and that this contraction is due to the fact that the concrete has been hardened in air.

The following results were obtained by investigations made by the same authorities and others, showing the effects of neat cement and mortar when hardened under water. The test pats or cubes of neat cement and mortar, after the final set, were immersed and kept under water for a considerable period of time. The results prove that neat cement when hardened under water shows a slight expansion, while mortar composed of one part Portland cement and three parts sand shows an expansion, but less in proportion than the neat cement.

SOME CONCLUSIONS.

Reducing these conclusions to figures, and taking the average results obtained by various authorities, figuring the expansion and contraction in percentage, the writer finds the following results :—

Neat Portland cement hardened in air at the end of sixteen weeks shows a 0·15 per cent. contraction.

One to three mortar hardened in air at the end of sixteen weeks shows a 0·05 per cent. contraction.

Neat Portland cement hardened under water at the end of sixteen weeks shows an expansion of 0·05 per cent.

One to three mortar hardened under water at the end of sixteen weeks shows an expansion of 0·015 per cent.

Without going further into the matter of figures, it is safe to state that the expansion and contraction is less for shorter periods than sixteen weeks, and that the percentage will be a trifle greater if carried beyond sixteen weeks or up to six months or a year.

We can, therefore, conclude that in a rich mortar there is more neat Portland cement on the face, and, therefore, a greater percentage of contraction of the surface ;

also, that a less rich mortar will show a proportionately less percentage of contraction, and that if the concrete were kept wet and protected (which is equivalent to hardening under water), hair cracks and crazing would be avoided.

SOME REMEDIES.

In the past this trouble has been partially overcome by brushing off the surface of the concrete or cement stone with a stiff steel brush, or by scrubbing the surface with a cement brick and wet sand, thus partially removing what might be termed a neat cement face. It has been found, however, that this does not entirely overcome the trouble, the remedy proving but temporary, the cracks appearing several months afterwards. The brushing or scrubbing is merely an assistance ; the real remedy lies in keeping the surface thoroughly and continuously wet as long as possible. It is unfortunate that this rule is seldom observed, and that in its non-observance good results are sometimes obtained. The worker in cement is thus influenced to disregard a matter of considerable importance in concrete construction. That good results are obtained from a disregard of these principles is largely a matter of luck. If the weather be damp for a number of days after the concrete has set, the object has been partially brought about by nature ; then again, the surface may have been so placed as to escape exposure from the wind or sun, which would tend to dry it, and was kept wet by the excess of water in the concrete. It is desirable to have the surface of the concrete or cement stone as near the same texture as the body of the concrete.

The only permanent remedy which will eliminate entirely these objectionable features is the removal of as much of this excess of neat cement collected on the surface as is possible as soon as the moulds are taken down. The surface should then be kept wet by the application of wet sand sprinkled from time to time with water, or hanging wet cloths over the perpendicular surfaces, keeping the exterior wet and the cloths wet by sprinkling or by any other method which will accomplish this result. The surface should be kept continuously wet for a sufficient length of time to enable the cement to attain ultimate crystallisation. By so doing the effect is practically the same as that of hardening under water. It is reasonable to conclude that if so treated the surface will slightly expand, but not to a greater extent than the body of the concrete which is already wet. It is not amiss to bring this whole subject as prominently as possible before those having charge of concrete construction, endeavouring to impress upon them the necessity of keeping concrete protected and thoroughly and continuously wet for as long a period as economy will permit.

BOOKS RECEIVED.

Arrangements are being made by which it is hoped that it will be possible to present a record of all books on concrete, reinforced concrete, steel frame buildings, cement and steel, published at home and abroad, and of these the more important ones will be summarised and reviewed on somewhat novel lines.

A number of books have already been received, but they will not be dealt with until the next issue.—ED.

MEMORANDA.

Memoranda and News Items are presented under this heading, with occasional editorial comment. Authentic news will be welcome.—ED.

The Increasing Interest in Reinforced Concrete.—The rapidly growing interest in concrete and reinforced concrete may be gauged from the number of papers, not only being read before the great technical institutions which embrace all subjects of constructional interest in their programme of work, but also being discussed in technical societies associated with work of an essentially specialist character. To mention a recent instance, the concrete tank is apparently being accorded considerable attention by such an institution as the London and Southern District Junior Gas Association. It is almost impossible to cope with the innumerable data we receive dealing with various aspects of applying concrete and reinforced concrete in modern structural work, but it is a matter of congratulation that so many minds are now at work considering the matter, for it is only by a considerable expenditure of thought representative of the many interests concerned that the problems still unsolved can find correct solution.

* * *

The Steel Industry and Reinforced Concrete.—Parties interested in the steel industry have frequently looked askance upon the introduction of reinforced concrete, although they have no reason to complain, seeing that the simultaneous introduction of steel frame buildings with concrete floors and roofs absorbs an enormous amount of steel girder work.

We are glad to see that the *Iron Trades Review* takes no pessimistic view of this matter. We ourselves believe that the introduction of reinforced concrete, simultaneously with the introduction of steel frame construction in this country, means heavy additional work for our shops, both in girder work and in many forms of plain and special bars used in reinforced concrete.

* * *

Prize Essays on Cement.—Premiums have been offered to the extent of £150 by a committee representing the Prussian Government and the German Association of Portland Cement Manufacturers, for the best paper on the processes which take place in the hardening of hydraulic cement.

* * *

Adulteration of Cement.—We mention under Editorial Notes the dangerous manner in which fictitious Portland cement, namely, natural cement, reaches this country, and is sold under false labels. The natural cement in respect to which the complaints are most general is Belgian. We now see from the *Echo Industriel* that Belgian technical professions also have to contend with considerable trouble from unscrupulous cement merchants, for whilst it would apparently be criminally fraudulent and punishable to sell natural cement for Portland cement, it does not appear so dangerous for the salesman to sell adulterated Portland cement in which natural cement is mixed. For this reason a public warning has now been issued in Belgium, with a view of preventing engineers and contractors being victimised by the adulteration of Portland cement. Thus, even in the country of origin, efforts are apparently being made to put a stop to the trading of unreliable and dangerous cement.

Loose versus Rigid Stirrups in Reinforced Concrete.—For some time past engineers have seen the necessity of providing for shearing strains in reinforced concrete girders and beams. Several systems have been patented to accomplish the desired results, some using rods bent up at the ends and others using plain rods and stirrups, or shear members. Tests are being conducted at home and in different parts of the world with the view of throwing additional light on the subjects. In the current issue we present particulars of an official test undertaken at Paris at the instance of Mr. M. Kahn, of Detroit, U.S.A., with two beams reinforced respectively with loose and rigid stirrups. The object apparently was to determine whether loose stirrups would slip along the bars, thereby allowing failure by shear, or whether it was necessary to have a rigid connection between the shear members and the stirrups. Engineers advocating the use of loose stirrups claim that the concrete surrounding the bars is sufficient to transmit the strain of the stirrups into the bar. Those advocating the use of rigid connections between the shear members and the diagonals claim that this concrete in question, being the farthest from the neutral axis, and also being in tension, is the first to fail and break away, thus preventing the transmission of the strain. The test recorded, although of course not final, calls for the close attention of all concerned.

* * *

The Mechanical Bond of Bars in Reinforced Concrete.—We observe with interest that an indented bar is being put forward for reinforced concrete. The company advocating the introduction of this bar argues that its primary feature is its greater adhesion to concrete owing to the mechanical bond formed by its indented surface and a consistent section, thus utilising the full sectional area in the resistance of stresses. These and similar bars have, we believe, been applied on a large scale in the United States, and we shall be interested to see the results of comparative tests regarding strength, fire-resistance, etc., between reinforced concrete where such bars are employed *versus* work where the ordinary round bar is employed.

* * *

Reinforced Concrete Chimneys near London.—We note with great interest that the sugar refinery of Messrs. Lyle and Sons, at Victoria Docks, is to be the first works in this country to have a reinforced concrete chimney. The chimney will be 260 ft. high, with an internal diameter of 20 ft. at the top, and will be built on the Weber system. The second firm to erect a chimney of this type are the Associated Portland Cement Manufacturers, who are putting one in hand at the Knight, Bevan and Sturge Works, Northfleet.

* * *

Coast Erosion.—The subject of coast erosion will probably mean a new development in the application of reinforced concrete, and it is a sign of the times that a popular paper such as *Country Life* should devote space to this important question, and give examples of the possible remedies with the aid of the economical reinforced concrete groyne. We hope to deal specially with this subject of groynes in a future issue, but in the meantime we think that engineers interested in sea defences should certainly accord careful consideration to the obvious advantages of reinforced concrete, both from the practical point of view and from the economical one of first cost and maintenance.

NEW WORKS IN CONCRETE

AT HOME AND ABROAD.

Under this heading reliable information will be presented of new works in course of construction or completed, and the examples selected will be from all parts of the world. It is not the intention to describe these works in detail, but rather to indicate their existence and illustrate their primary features, at the most explaining the idea which served as a basis for the design.—ED.

THE JEFFERSON STREET REINFORCED CONCRETE ARCH BRIDGE, SOUTH BEND, INDIANA, U.S.A.

Jefferson Street, South Bend, is the principal residential street on the east side of the St. Joseph River. The street is 82 ft. 6 in. wide. The river at this point has very little current, and a maximum variation from low to high water of about 5 ft. by reason of a dam situated some 300 ft. below the bridge side.

The design adopted was an elliptical arch of concrete reinforced with steel arch ribs, consisting of four angles latticed and connected over the piers by angles. The ribs were made in two sections at the shop, and given a shop coating of cement grout.

The bridge has a roadway of 52 ft. between curbing, and two sidewalks, 10 ft. each, and is designed to carry, besides pedestrians and vehicles, two electric street car tracks, with conduits for the public mains.

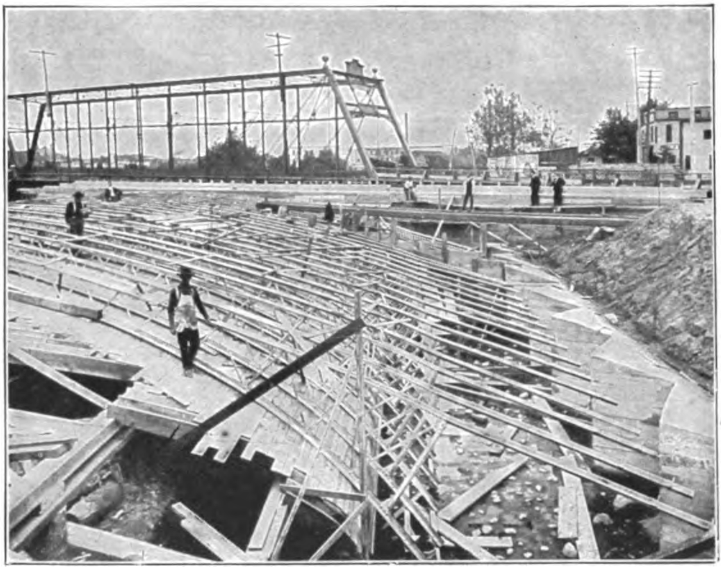
By reason of the river being at an angle of 60 deg. with the axis of the street, the bridge has been designed as a skew bridge. The grade is continuous also across the bridge, requiring a 1·3 per cent. grade.

Over the piers the sidewalks are corbelled out and rest on columns which form one of the principal architectural features of the structure, the variation in grade at the piers being taken up to the column height.

At the ends of the bridge also the sidewalks are carried out further from the axis of the bridge, making it at the ends practically the full width of the street.

Steps lead from the bridge down into the park at the east, and the east span projects beyond the river wall, permitting of a passage way under the arch, leading down to steps at the water's edge.

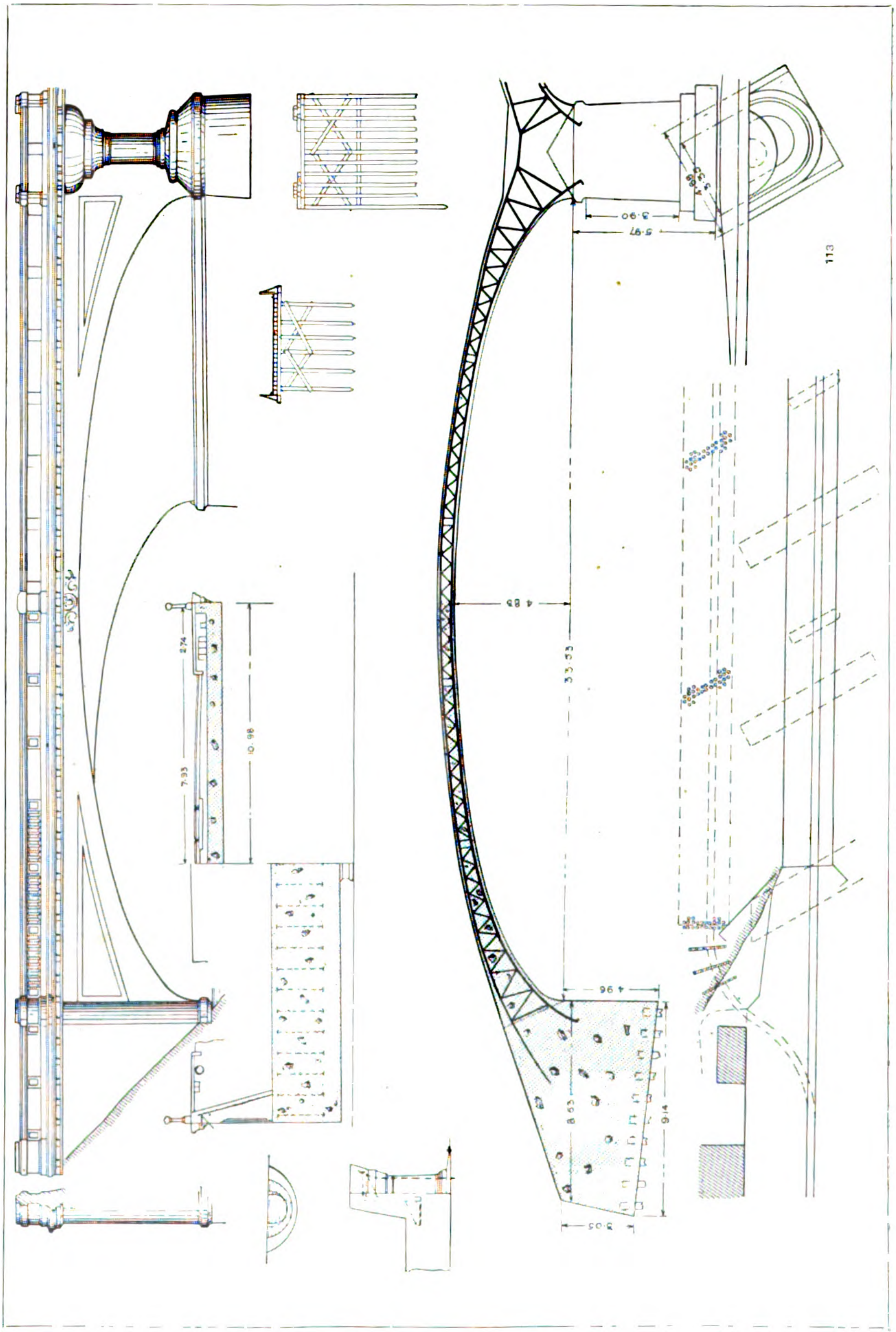
Work began in August, 1904. The cost of the bridge was $119,000, with an extra for piling of 43 cents per foot driven.



Reinforced Concrete Arch Bridge in Course of Construction, Indiana, U.S.A.

The piers and abutments are carried down into the clay with open cofferdams, and about 2 ft. of the piling projects up into the concrete. The pier footings are about 17 ft. below the ordinary stage of the river, and the bed of the abutment concrete is inclined upwards towards the back of the abutment.

The concrete has been placed in the piers



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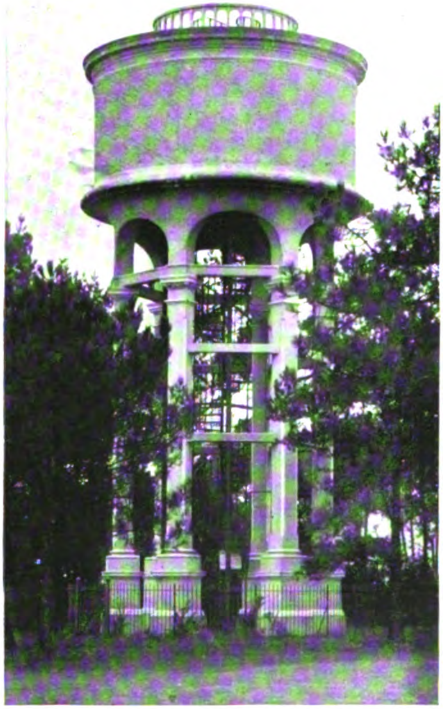
REINFORCED CONCRETE ARCH BRIDGE, INDIANA, U.S.A.

and abutments in such a manner as to be separated over the spring lines and the arched masonry (forming a day's run), extends longitudinally across the arch, and thus has a right-angle bearing and thrust against the piers and abutments. In fact, the longitudinal sections thus avoid the skew arch effect. The longitudinal ribs are joined together by steel bars at the top and bottom chords of the steel arches, spaced 10 ft. apart.

The top of the arches is plastered and then coated with coal tar pitch to more effectually waterproof the surface.



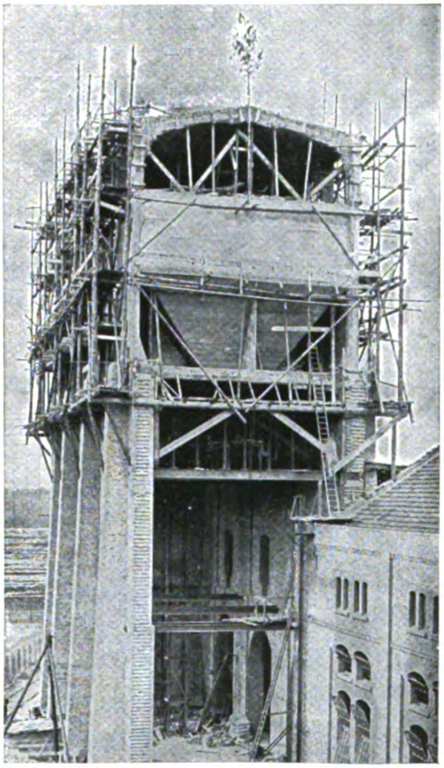
Reinforced Concrete Water Tower at Bournemouth

The gravel used in the bridge was found on testing it, to carry the proper proportion of sand, and the foundation concrete was composed of one part "Universal" Portland cement to 8½ parts of gravel, the spandril walls are composed of concrete proportioned one part of cement, 7½ parts gravel, and the arch concrete is mixed in the proportion of one part cement to 5 parts gravel.

The facing of the entire bridge is of cement mortar, 1 in. in thickness, applied at the time the concrete is laid. The forms, which are planed smooth, and the edges bevelled to make a tight joint, are treated with a coat of soft soap before laying the concrete, so as to remove the effect of the board marks as much as possible.

Mr. A. J. Hammond, A.Am.Soc.C.E., is the designer of the bridge, and has supervision over the construction for the county.

The reinforcement was designed in accordance with the formula of Professor von Emperger, *i.e.*, was not on what is generally known as a special system. *Extract from "Beton und Eisen."*



Reinforced Concrete Bins at Manheim.

NEW REINFORCED CONCRETE WATER RESERVOIR AT BOURNEMOUTH.

The capacity of the tower is 15,000 gallons, and the total height 45 ft. The reservoir is supported on six square reinforced concrete pillars, 35 ft. long by 18 in. square, and finished with arches to receive the tank, the whole forming a structure pleasing in appearance, which contrasts very favourably with iron structures for similar purposes.

The following is a report of the testing of the tank on completion by the Borough Engineer :—

"After fixing the necessary instrument for deflection measurement under the bottom of tank of tower, the water was turned on and the tank allowed to fill up to a depth of 4 ft., nearly 50 per cent. of its capacity, and the instrument showed a deflection of $\frac{1}{10}$ of a millimetre. The water was then shut off and the tower and tank left in the same condition for four days.

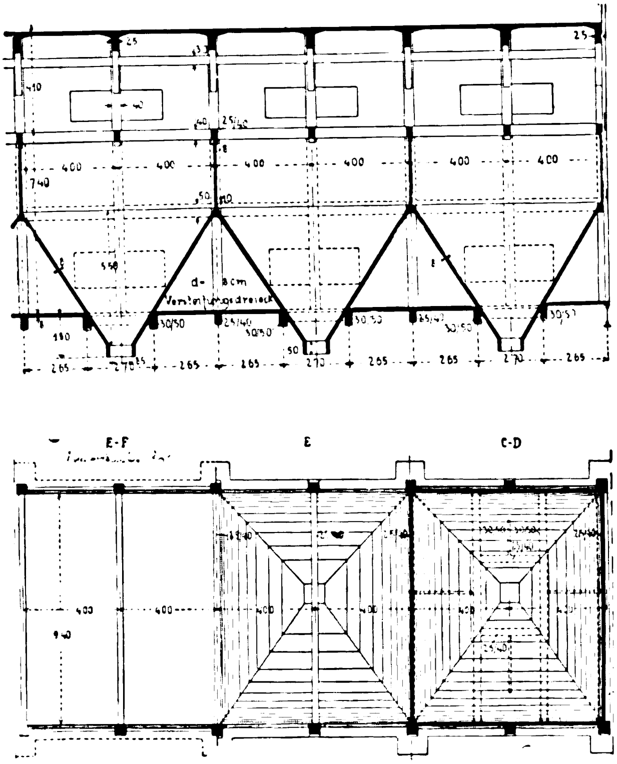
Four days after the first trial, the deflection instrument was again placed in position and the water turned on, when the water reached 90 per cent. of its capacity. The instrument showed a slight deflection, and reached a maximum of $\frac{1}{125}$ part of an inch of deflection when the tank was overflowing, the water in the tank then being 9 ft. 6 in. deep. This deflection of $\frac{1}{125}$ of an inch, compared to the clear span, which is 15 ft., shows a deflection of $\frac{1}{22500}$ part of the clear span. If account is taken that in beams $\frac{1}{600}$ part of the span is allowed for deflection, the deflection in the tower may be taken as entirely insignificant. After leaving the water in the tower to the overflow level for 45 minutes, the level was then reduced until 90 per cent. of the water was still left in the tank, at which the deflection of $\frac{1}{125}$ of an inch entirely disappeared."

This tower was designed by Mr. F. W. Lacey, M.Inst.C.E., F.R.I.B.A., borough engineer, on the Hennebique system, and the work was carried out by Messrs. Lang and Jones, of Liskeard, Cornwall.

BINS AT MANHEIM.

Some large bins have been recently constructed for a factory at Manheim, and the illustrations presented herewith practically explain themselves. The bins are located at the top of a brick building. Three bins have been completed with a total length of about 24 metres, and additional ones are contemplated shortly.

Extract from "Beton und Eisen."



Reinforced Concrete Bins at Manheim.

NEW WORKS IN STEEL

AT HOME AND ABROAD.

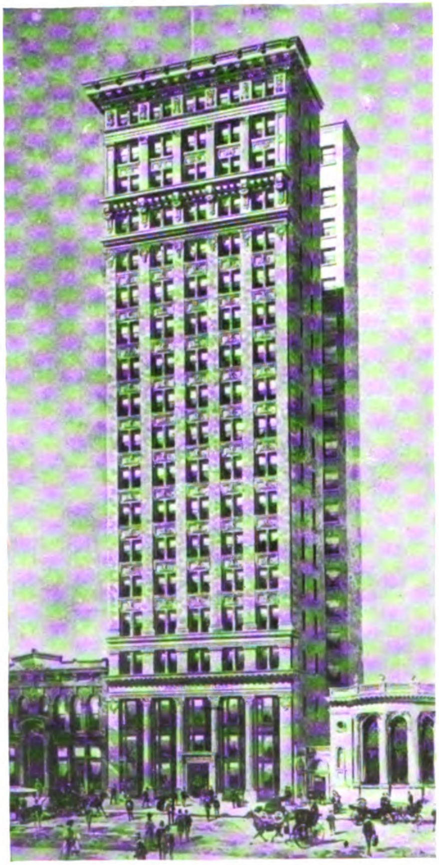
Under this heading the application of systems of steel frame construction will be accorded primary attention. Instances in which problems of considerable difficulty have had to be overcome will receive illustration accompanied by short descriptive notes.—ED.

THE MACHESNEY BUILDING OF PITTSBURG.

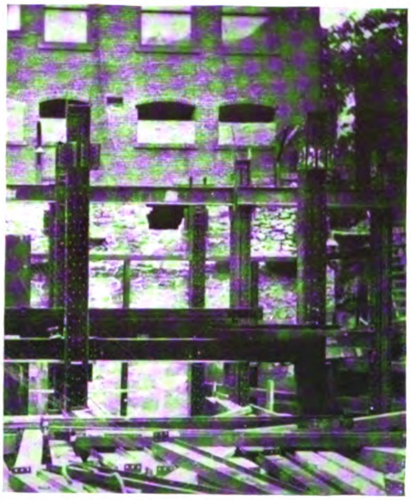
The Machesney building is nineteen stories high, with an additional mezzanine floor, and occupies only 60 ft. 2¼ in. frontage, by a depth of 80 ft. How to handle this small area to advantage and provide a steel frame that would meet all the requirements of the loads and stresses, was a problem of considerable difficulty, enhanced by the fact that the building is surrounded on three sides by old structures, whose owners would not accept any proposal for party walls. In addition to this, the small area of the building required the cellar level to be carried down about 35 ft. below the street to give adequate room for the machinery. As this brought the cellar level about 20 ft. below the three adjacent walls of fairly high buildings, it was necessary to shore up these walls and to build new ones below them down to the new level, whilst the refusal to share these walls as party walls meant a cantilever system of foundations. A partial idea of this work may be had from *Fig.* 2, showing three of the holes in the walls where the shoring had been removed after the construction of the new walls below, whilst *Fig.* 3 shows the design for the cantilever foundations.

The question of wind effect received much careful consideration, and the scheme adopted was the simple principle of binding the building externally at each floor level with deep girders extending in all cases outside the columns and completely around the frame. This arrangement is well illustrated in *Fig.* 4, which also gives an idea of the double interior girders of the lower stories straddling the columns and acting as struts for wind effects, in addition to receiving the load of the floor beams.

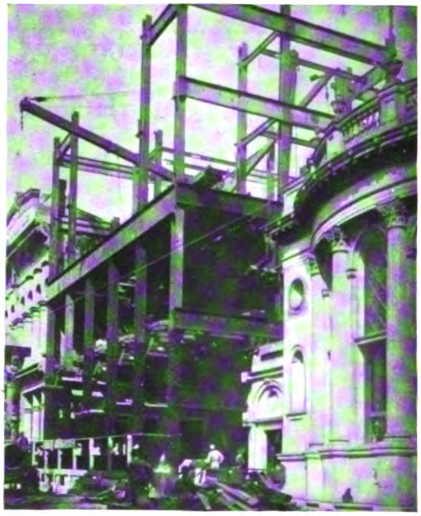
These interior girders, being designed as a part of the wind bracing, have their connections to the columns made with the angles of their webs figured for load carrying with additional seat and hitch angles riveted to their top and bottom flanges figured for wind. This system of wind bracing dispenses with the diagonal or portal bracing so often used in the United States, which is usually such a nuisance and furnishes



THE MACHESNEY, BUILDING, PITTSBURG.
Fig. 1. Genera View of Building completed.



THE MACHESNEY BUILDING, PITTSBURG,
Fig. 2. Lower Framing.



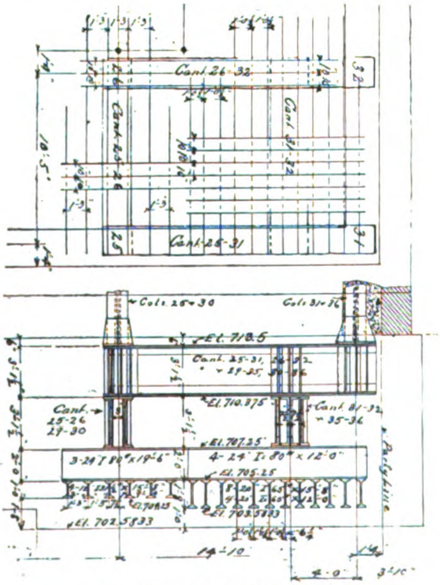
THE MACHESNEY BUILDING, PITTSBURG.
Fig. 4. In course of construction.

so much ground for argument to the engineer.

The plate and angle type of columns is used throughout the structure. The connections of beams and girders are original in many points, having a full opening or pocket between the column and the beam, or girder. This allows the free passage of pipes and wires, which of necessity in this building must be carried from story to story in this way.

The total tonnage of structural steel involved is about 1,400 tons. This was rolled and fabricated by the Carnegie Steel Company, of Pittsburg, the architect being Mr. T. H. Scott.

Extract from "The Fireproof Magazine."



DETAIL OF FOUNDATION.
Fig. 3.

NEW USES OF CONCRETE

AT HOME AND ABROAD.

Under this heading reliable information will be presented as to new uses to which concrete and reinforced concrete are put, with data as to experience obtained during the experimental stage of such new applications of these materials. The use of reinforced concrete as a substitute for timber in exposed positions is one of the questions of the moment. Railway sleepers, telegraph posts, fence posts, etc., of concrete are being tried. Similarly efforts are at present being made to prove that reinforced concrete is an excellent substitute for brickwork, where structures of great height are required, such as factory chimneys, lighthouses, observation towers, etc.—ED.

REINFORCED CONCRETE CHIMNEYS.

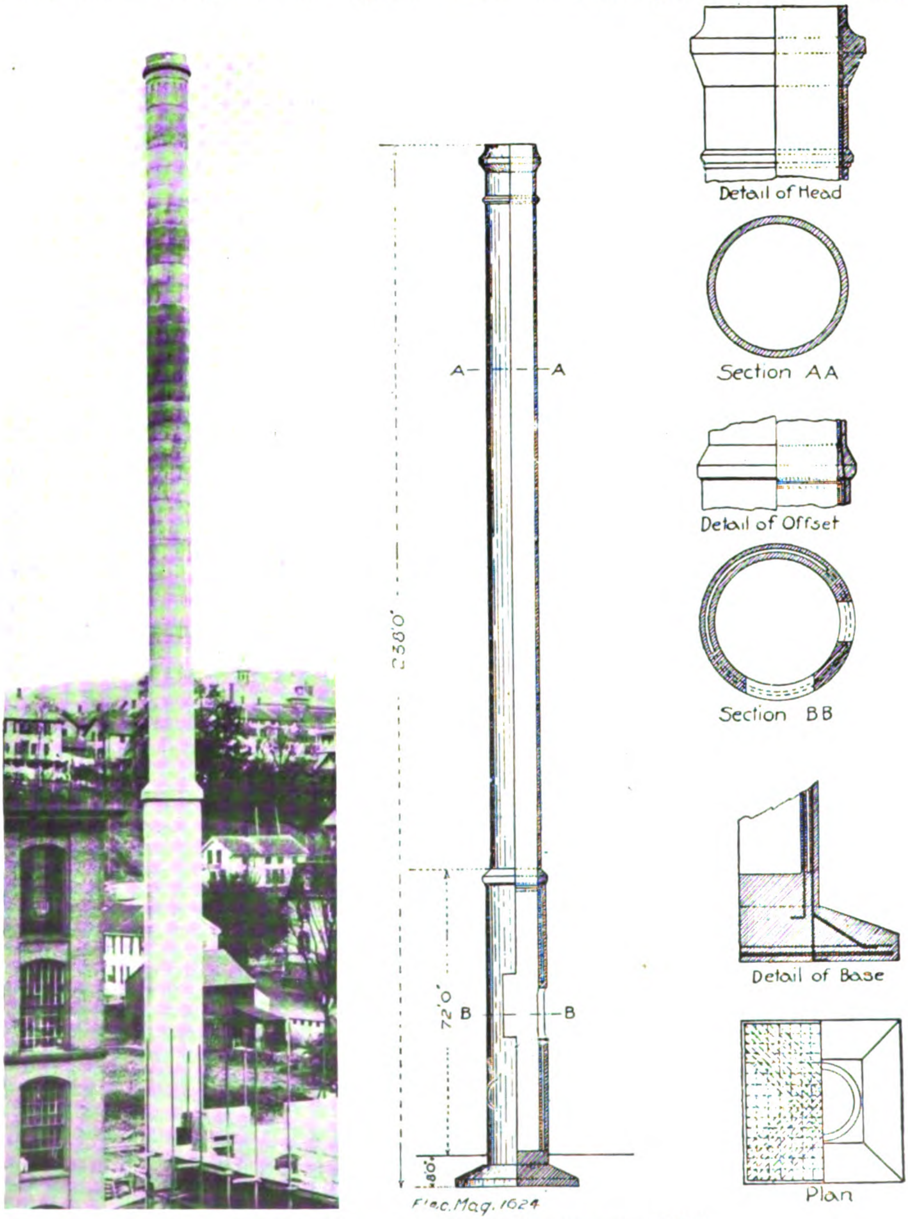
Of new uses to which reinforced concrete is now being put, special mention should be made of the high factory chimney. Numerous examples are to be found in the United States, and their introduction has been found to be most satisfactory. Two examples of reinforced concrete chimneys have also now been put in hand near London. We thus reproduce from the *Electrical Magazine* a commentary on the subject.

High Chimneys.

During the past year Mr. G. C. Mason, has had the opportunity to erect two chimneys which dwarf into comparative insignificance the biggest chimney of one year ago. One chimney erected for the Portland General Electric Company has an inside diameter of 12 ft. and rises 230 ft. above grade. Another built for the Tacoma Smelting Company, in Tacoma, Wash., has an inside diameter of 18 ft. and stands 300 ft. above grade. The latter is to-day the largest chimney built of reinforced concrete. There are three kinds which naturally suggest themselves — brick, steel, and concrete. Where brick is cheap and ground space not too valuable this form of stack offers several advantages. Any shape or form of chimney is easily constructed, and the brick offers the necessary resistance to moderate heat. It offers considerable friction by reason of the many joints between the brick, and where intense heat is to be carried the brick chimney must be lined with fire-brick and fire-clay. The steel chimney is the cheapest to construct under reasonable conditions, but is the most expensive to maintain and has the shortest life of the three. The steel chimney, if made self-supporting, again becomes expensive, and the guys for one of shell construction are certainly not ornamental and may be a source of danger. If kept clean, the steel chimney offers little friction to the air, but it is too good a conductor of heat to make an ideal construction.

Monolithic Chimneys.

The third form seems to meet the requirements to a far greater extent. Monolithic concrete is smooth on the surface, a non-conductor of heat, requires no lining to resist any temperature, at least up to 1,500 deg. F., requires no expense for maintenance, and because of its inherent properties becomes stronger and better with age. As to first cost, the three usually rank—steel, concrete, and brick. As to final cost, they almost invariably shift this order to concrete, brick and steel. The difference even in first cost between concrete and steel is rarely so great as to warrant the use of steel for this reason for any but temporary purposes. The ground space, which is often very important, is economised to the greatest extent by the use of reinforced concrete—the saving over brick being about one-third. Until the development of a suitable system of reinforcing concrete it is impossible to use it in tall chimney construction, the tensile strength of concrete being insufficient to economically resist the wind stresses. At this time it is not necessary to more than enumerate the principles upon which reinforced concrete depend. The steel is embedded in the concrete to take care of the tensile stresses, the concrete itself resisting those due to compression. Steel properly embedded in concrete does not rust or otherwise deteriorate. Steel and concrete in proper combination act not as two materials, but, by reason of their adhesion, practically become one and act together. The coefficient of expansion, which of course is a matter of considerable moment in a chimney subjected to great heat, is for all practical purposes the same in both steel and concrete. Much has been written about the adhesion of concrete to steel, very much of which is for business purposes rather than engineering. This much seems to have been proved—that the adhesion varies directly with the exposed surface area of the steel, and as the strength in tension depends upon the sectional area, the end desired is to get the greatest surface area exposed for adhesion with the requisite cross-section for tension. Inasmuch as T-steel gives a superficial area of almost twice that of round or square bars, the T-shape was used in both these chimneys.



Reinforced Concrete Chimney, Rochester, U.S.A.

RESEARCH WORK.

AT HOME AND ABROAD.

We propose to present particulars as to research work that is being conducted at home and abroad with structural materials generally, and more particularly in respect to cement and steel. General research work of this description is being conducted on an extensive scale in the United States and in Germany, as a rule with the aid of public funds. The data arrived at should be of value to the British reader.—ED.

THE UNITED STATES GOVERNMENT ADVISORY BOARD ON STRUCTIONAL MATERIALS.

Among the interesting exhibits at the St. Louis Exhibition of 1904 were the United States Official Fuel Testing Plant and the Portland Cement Model Testing Laboratory of the Association of American Portland Cement Manufacturers. These working exhibits accomplished much good work during the exhibition season, and led to a Government grant being made in the interests of further research in matters appertaining to the investigation of sands, gravels, stone and other constituent materials of mortars and concretes, as well as to the study of mortars and concretes. The equipment of the Model Testing Laboratory referred to has now been added to, and Mr. Richard L. Humphrey, M.Am.Soc.C.E., has been put in charge as secretary to an influential and representative Advisory Board, constituted to supervise these and other investigations.

Heretofore, such investigations have been conducted by those in the employ of the producer or consumer at such time and under such conditions as would not seriously interfere with routine work. They were, therefore, necessarily incomplete, and lacked the thoroughness desirable. The present investigations will be conducted by disinterested and wholly impartial parties, and possessing the requisite time and money, and the results should therefore prove invaluable. The Advisory Board has further been given an official status which should materially assist its operations.

PROGRAMME OF WORK.

As to the programme of these tests the particulars are of the utmost importance to all interested in structural materials, and we thus present the main features of the first series of investigations regarding cement mortars and concrete.

These investigations will comprise :—

I.—Examination of Constituent Materials.

Sands, gravels, stone, stone screenings slags, cinders, etc., to be collected by a special representative of the Testing Laboratory sent out for that purpose.

A. Examination of Deposit as to the extent and nature of the material from which the samples are collected.

B. Physical Tests in the Laboratory: (1) Mineralogical examination, (2) Specific gravity, (3) Weight per cubic foot, (4) Sifting (granularmetric composition), (5) Percentage of silt and character of same, (6) Percentage of voids, and (7) Character of stone as to percentage of absorption, porosity, permeability, compressive strength, and behaviour under treatment.

C. Chemical Analysis as to the character of the stone, silt, etc., used in these tests.

II.—Tests of Mortars.

Tests of Mortars made with a typical Portland cement and sand, gravel and stone screenings. The typical Portland cement to be prepared by thoroughly mixing a number of brands, each of which must meet the following requirements :—

Specific gravity, 3·10.

Fineness, residue not more than 8 per cent. on No. 100 and 25 per cent. on No. 200 sieve.

Time of setting :
  Initial set, not less than 30 minutes ;
  Hard set, not less than 1 hour or more than 10 hours.
Tensile strength :
  24 hours in moist air 175 lb.
  7 days (1 day in moist air, 6 days in water) 500 lb.
  28 days (1 day in moist air, 27 days in water) 600 lb.
One part cement, 3 parts standard sand :
  7 days (1 day in moist air, 6 days in water) 175 lb.
  28 days (1 day in moist air, 27 days in water) 250 lb.

Constancy of volume with pats of neat cement, 3 in. in diameter ½ in. thick at centre, tapering to a thin edge, shall be kept in moist air for a period of 24 hours : (A) A pat is kept in air at normal temperature and observed at intervals for at least 28 days ; (B) Another pat is kept in water maintained as near 70 deg. F. as practicable and observed at intervals for at least 28 days ; and (C) A third pat is exposed in an atmosphere of steam above boiling water in a loosely closed vessel for five hours.

NOTE : These pats must remain firm and hard and show no signs of distortion, checking, cracking, or disintegration.

The cement shall contain not more than 1·75 per cent. anhydrous sulphuric acid or more than 4 per cent. magnesium oxide.

A test of the neat cement must be made with each mortar series for comparison of the quality of the typical Portland cement.

A. PHYSICAL TESTS IN LABORATORY : (1) Tensile strength with one part cement to varying percentages of material under test for 7, 28, 90, 180, and 380 days ; (2) Compressive strength with one part cement to varying percentages of material under test for 7, 28, 90, 180, and 360 days ; (3) Transverse strength with one part cement to varying percentages of material under test for 7, 28, 90, 180 and 260 days ; (4) Yield in mortar ; (5) Tensile strength with cement, material sieved to one size, 7, 28, 90, 180, and 360 days ; (6) Compressive strength with cement, material sieved to one size, 7, 28, 90, 180 and 360 days ; (7) Transverse strength with cement, material sieved to one size, 7, 28, 90, 180, and 360 days ; (8) Porosity ; and (9) Permeability.

III.—Tests of Concrete.

Tests of concrete made with stone, stone screenings, gravel, sand, cinder, slags, etc.

A. PHYSICAL TESTS IN LABORATORY : (1) Tensile strength with different mixtures as to proportion and size of the aggregates, for 30, 90, 180, and 360 days ; (2) Compressive strength with different mixtures as to proportion and size of the aggregates for 30, 90, 180 and 360 days ; (3) Transverse strength with different mixtures as to proportion and size of aggregates for 30, 90, 180 and 360 days ; (4) Absorption ; (5) Weight per cubic foot ; (6) Modulus of elasticity in compression and tension ; (7) Character crushed material used : (*a*) Weight per cubic foot, (*b*) Size, (*c*) Percentage of voids, (*d*) Percentage of silt ; (8) Porosity ; (9) Permeability ; (10) Fire-resisting qualities ; (*a*) Effect on hardening concrete, (*b*) Effect on hardened concrete ; (11) Freezing tests ; (12) Yield of concrete ; (13) Effect on vibration : (*a*) On hardening of plain and reinforced concrete, (*b*) On hardened plain and reinforced concrete ; (14) Protective influence against corrosion of metal ; (15) Adhesion of concrete to metal for varying periods under varying conditions, up to at least 3 years : (*a*) Embedded, (*b*) On flat surfaces.

B. FULL SIZE TESTS : (1) Beams of various spans, sections and compositions ; (2) Building blocks and bricks as to : (*a*) Compressive strength, wet and dry mixtures, (*b*) Transverse strength, wet and dry mixtures, (*c*) Shearing strength, wet and dry mixtures, (*d*) Absorption, wet and dry mixtures, (*e*) Permeability, (*f*) Methods of waterproofing, (*g*) Fire-resisting qualities, (*h*) Efflorescence.

IV.—Tests of Reinforced Concrete Beams.

A. PHYSICAL TESTS IN LABORATORY : (1) Varying percentages of round, square and flat bars in bottom ; (2) Varying percentages of round, square and flat bars in bottom and top.

TESTS WITH CONCRETE

AT HOME AND ABROAD.

We consider that the absence of reliable information as to the various tests carried out with concrete both at home and abroad has frequently led to misconceptions as to the qualities of this material, and we shall thus for the present accord considerable space to the presentation of authentic data that may be of service to those employing concrete in its various forms. The tests which will particularly call for our attention are those relating to strength, fire-resistance, and waterproofing.—ED.

Some Remarkable Tests indicating "Flow" of Concrete under pressure.

The accompanying illustration shows some rather extraordinary results which have been recently obtained at the Columbia University Testing Laboratory while Professor Ira Woolson was making a series of tests upon different methods of column construction for the American Column Company. These tests, which have been reported on in the *Engineering News*, can be summarised as follows:—

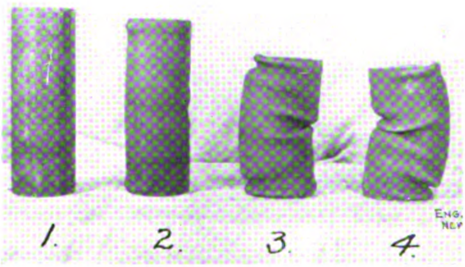
A series of short columns, 4 in. in diameter, and 12 in. long, were constructed by filling steel tubes of that size with a finely crushed stone concrete and allowing the same to set. The concrete in the columns tested was 17 days old at time of test and appeared to be very hard. The metal of the tubes was of different thicknesses, varying from $\frac{1}{8}$ in. to $\frac{1}{4}$ in. The heavier metal columns carried a load of 150,000 lb. without injury except a slight shortening of less than $\frac{1}{4}$ in. The columns with the light weight tubes began to show a marked deformation at about 120,000 lb. and this gradually increased until a load of 150,000 lb. was applied, when the tests were discontinued. The photograph shows what happened in different cases. No. 1 was unaffected by the full load, No. 2 had sustained a load of 115,000 lb. A bulging ring near the top and bottom shows that failure had just begun. Nos. 3 and 4 show excessive deformation due to increase of load. They were compressed $3\frac{1}{4}$ in. and $3\frac{1}{2}$ in., respectively. The diameter had correspondingly increased to about 5 in.

It was supposed that this excessive distortion had completely disintegrated the concrete and left it a powdered mass, but to the observers' surprise when the tube was sawed apart and removed, the concrete was found to have taken the exact shape of the distorted tube and was solid and perfect in every way possible.

The proof was positive that the concrete had actually flowed under the pressure like any plastic material. The concrete was apparently perfectly dry, and the pressure produced no sign of moisture anywhere.

In 1901, Professor Frank D. Adams, of McGill University, presented a paper before the American Geological Society in which he described some results he had obtained by compressing 1-in. cylinders of marble in steel tubes. He caused the cylinders to become larger and shorter by actually compelling the crystalline marble to flow.

So far as we know these tests are first evidence on record that concrete could be made to show this remarkable phenomena of flow.



It would almost seem as if large masses of concrete foundations surrounded by more or less yielding earth might do the same thing when subjected to excessive pressure.

From a geological standpoint the phenomenon is also interesting as illustrative of the way various rock formations were folded and distorted after they were formed.

We are happy to hear that further tests with concrete several months old will shortly be undertaken by Professor Woolson, with the view of seeing if there is similar mobility.

Fire Tests with Reinforced Concrete Floors.

We understand that the British Fire Prevention Committee is conducting an important series of fire tests with reinforced concrete floors, these tests being full sized tests under the severe conditions necessary for attaining classification as affording "full protection" against fire, which means that these floors are subject to a fierce fire followed by the application of water from a steam fire engine, carrying a load during the test. For classification "A" in the "fully protective" class, the test is one of 2½ hours' duration, followed by two minutes of water, and the load is 2 cwt. per foot super. For classification "B" the period is four hours' fire test, followed by the application of water for five minutes, and the load is 2½ cwt. per foot super.

The series of tests as far as arranged at present comprises, in the first place, two tests with ordinary concrete floors reinforced by small steel joists supported by—but not bolted or riveted to—heavy broad flange girders, the concrete in the one case being Thames ballast concrete, and in the other case, clinker concrete.

Next there are two tests with reinforced concrete floors designed on the "Coignet" system, a clinker concrete being used in the first and a slag concrete in the second test.

Another subject under review is a floor of broken brick concrete reinforced with expanded metal lathing, supported by ordinary girders protected by concrete

Four of the tests have already taken place, but the series can scarcely be finished until the middle of May, and it is not improbable that it will then be further extended so as to include some of the American systems of reinforced concrete not yet tested.

Of the tests already completed two reports (No. 107 and 108) have been issued by the Committee in April, namely, those on the two ordinary concrete floors, supported by broad flange girders, the girders having been provided by Messrs. H. J. Skelton and Co.

We take the earliest opportunity of presenting a short summary of the results and add two illustrations which speak for themselves, and we adopt, as before, a tabular form of summary. The results bear out in a most remarkable manner the experimental fire tests with floor bays described on page 60 of No. 1 issue, namely, that Thames ballast is quite unreliable as a fire resistant.

CONCRETE AS A FIRE RESISTANT.—Thames Ballast *versus* Clinker Aggregates.

Each floor measured 22 ft. by 15 ft. in three bays of 7 ft. span, and was loaded 2½ cwt. per ft. super.

Each test: 4 hours fire gradually increasing to about 1800° F., followed by 5 minutes of water under pressure.

Thames Ballast Concrete Floor.

In 22 mins. the soffit of the concrete floor began to split off in patches, and continued to do so during the test.

In 75 mins. the whole of the concrete casing to lower flange of one beam fell.

In 100 mins. ditto in respect to second.

The beams of the floor began to deflect in 20 mins., and contined to do so more rapidly after the concrete to the lower flanges fell, a max. deflection of 7 3/10 in. being reached.

Towards the end of the test the concrete to the north bay between the cross joists began to fall and wooden floor ignited.

At the conclusion of the test the lower flanges of the beams were red hot.

On the application of water more of the soffit fell, and eventually nearly the whole of the concrete between the cross joists in the north bay fell.

The max. permanent deflection of the floor four days after the test was 4⅞ in.

Both fire and water passed through the floor, which was badly damaged.

Clinker Concrete Floor.

In 25 mins. after the commencement of the test, small pieces of concrete began to split off soffit.

In 31 mins. two patches of concrete about 1 in. thick became detached from soffit of south bay and fell.

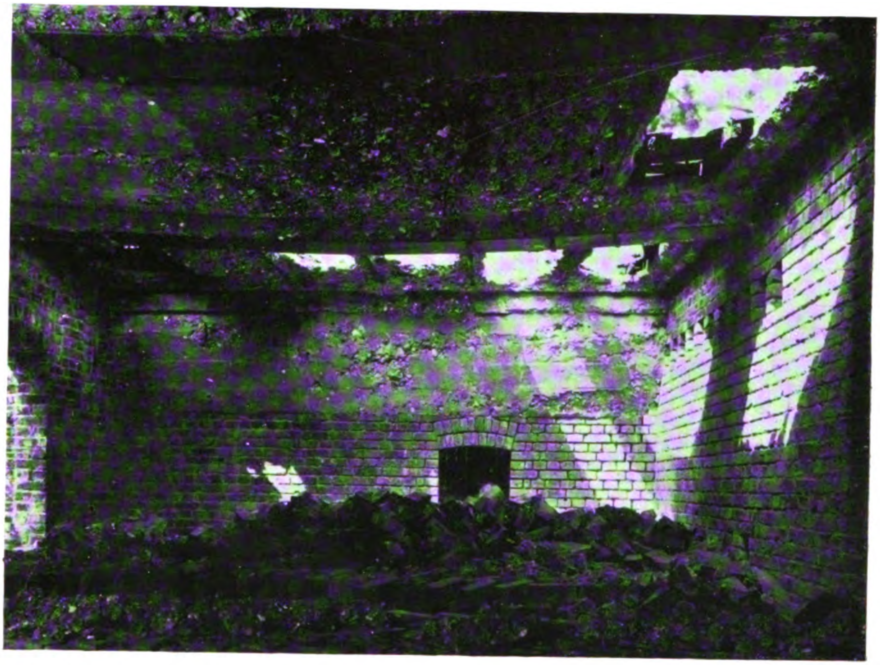
The max. deflection recorded was ·35 in. after 240 mins.

On the application of water the surface of the concrete was eroded. (See illustration.)

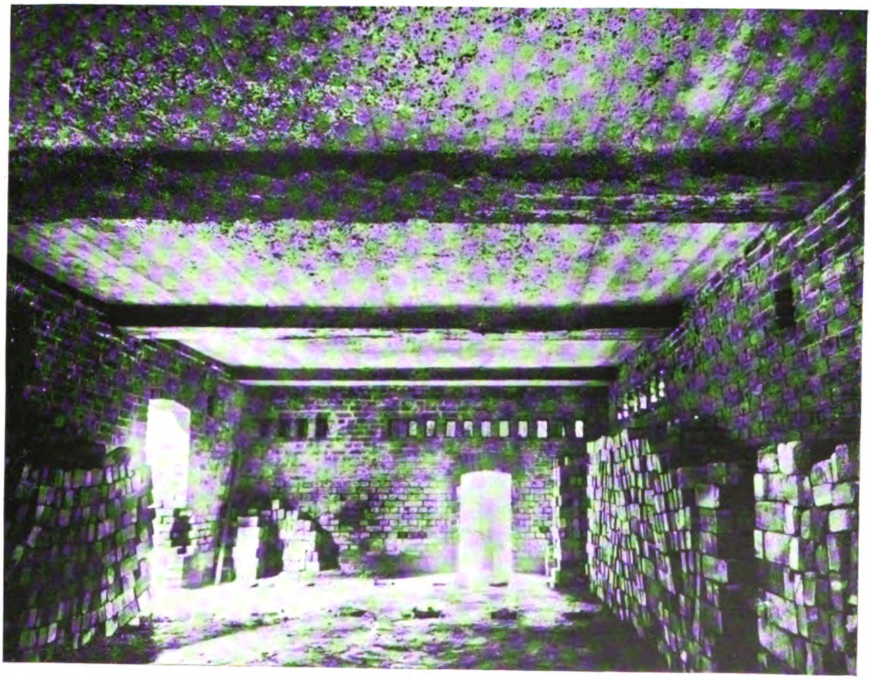
Some of the floor boards were discoloured by the heat on the underside, and a wood strip at one corner was charred.

Some fine diagonal cracks on the top of the floor extending about 3 ft. were found at three corners, also cracks on each side of the concrete over the top of beams.

Neither fire nor water had passed through the floor. The floor remained practically level and intact.



THAMES BALLAST CONCRETE FLOOR AFTER FOUR HOURS' OFFICIAL FIRE TEST.



CLINKER CONCRETE FLOOR AFTER FOUR HOURS' OFFICIAL FIRE TEST.

FRENCH OFFICIAL TESTS WITH REINFORCED CONCRETE BEAMS.

Loose Stirrups *versus* Rigid Shear Members.

We have received a copy of an official report issued by the French Government Laboratory (Conservatoire National des Arts et Metiers), recording the results of two tests with reinforced concrete beams having identical dimensions, aggregates and reinforcements, the one, however, having rigid shear members whilst the other had loose stirrups.

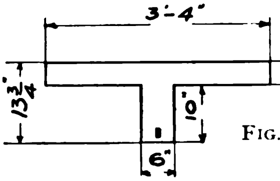


FIG. 1.

The following is a summary of the reports freely translated from the French. It claims attention more particularly as a test conducted in France where, until quite recently, the loose stirrup has been favoured.

Summary of Official Report.

Two concrete beams were recently tested at the Conservatoire National des Arts et Metiers, Paris, one being reinforced with plain rods and loose stirrups, and the other with plain rods, on which stirrups were rigidly connected. The two beams had exactly the same dimensions, and the tests to which they were both subjected were operated under the same conditions. Each beam was supplemented by a slab, as shown in *Fig.* 1, and rested on two stone supports 16 ft. 4⅞ in. apart. The beams were constructed by the staff of the laboratory. The concrete comprised: gravel, 836 lb.; sand, 902 lb.; Portland cement, 275 lb.; and water, 144 lb. After mixing, the sand and gravel together measured 16·10 cubic feet, and the proportion of cement per cubic yard became

$$\frac{275 \times 27}{16{\cdot}10} = 461 \text{ lb.}$$

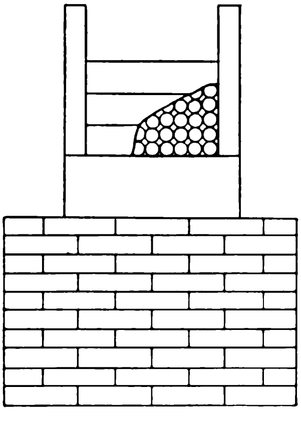
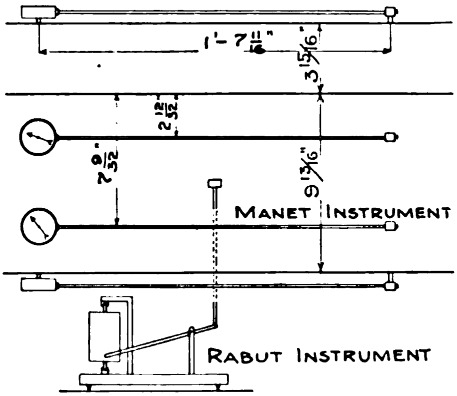


FIG. 3.

Of this concrete twelve cubes of fifty centimetres sectional area were made and tested at the same time as the beams. Their average was 1,330 lb. per square inch. The centering was struck after fifteen days.

Loading.

The tests took place one month after concreting. Cast-iron balls, weighing 17½ lb. each, were used for the loading. To avoid any chance of the balls rolling off, these were held in by a bottomless box, the internal dimensions of which were the same size as the floor. The beams were loaded symmetrically from the centre.



Records.

Two sets of records were taken, namely: (1st) *Measurement of Deflection at the centre of each beam.*—This measurement was taken by means of a Rabut indicator, showing the results twenty times the actual size, and enabling a measurement of within 1·40 of a millimetre. For the purposes of the test, an iron hook was fixed in the centre of the beam, and at the end of it was hung a wire held taut by a weight. The lever of the Rabut apparatus was attached to this wire. With this arrangement, the lever was made to follow the downward motion of the wire, and this motion was shown enlarged and registered by the apparatus.

(2nd) *Measurement of Deformation.*—These measurements were effected by the aid of four Manet recorders, on a length of 19·6 in.

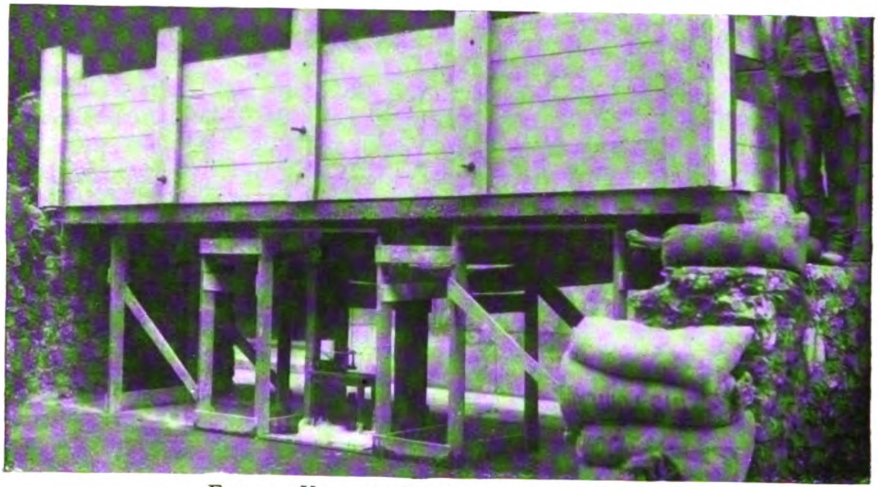


FIG 2. VIEW OF BEAM BEFORE LOADING.

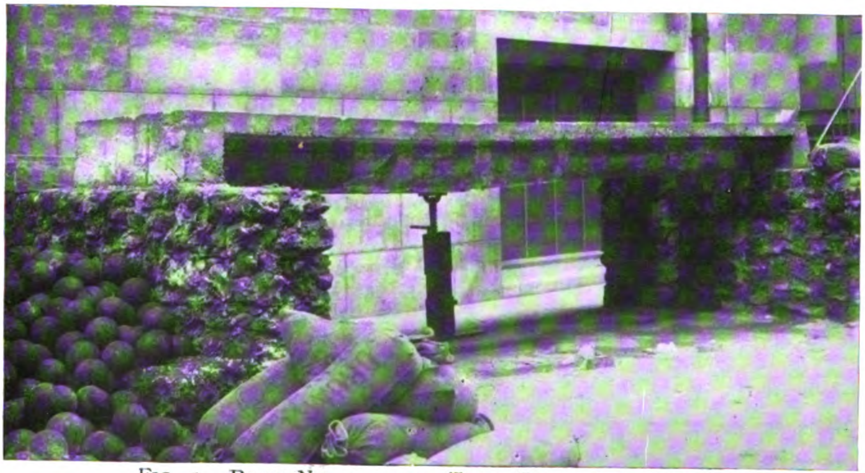


FIG. 5. BEAM NO. 1 AFTER TEST (LOOSE STIRRUPS).

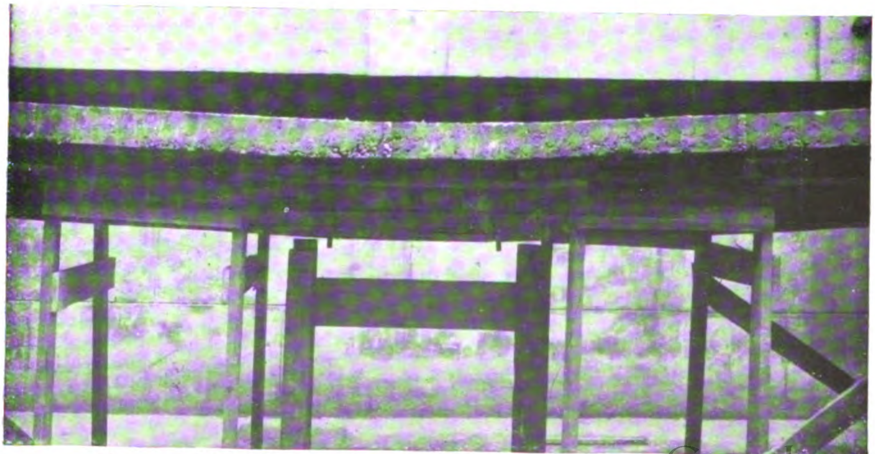
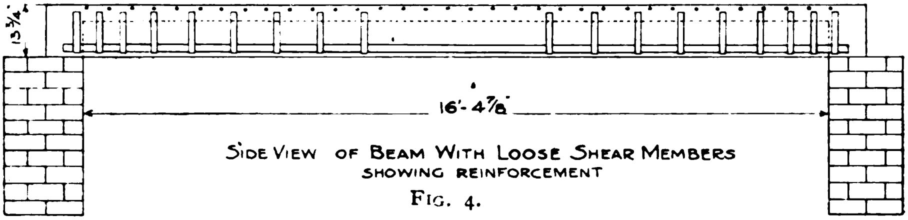


FIG. 7. BEAM NO. 2 AFTER TEST (RIGID SHEAR MEMBERS).

These appliances, which registered to $\frac{1}{200}$ of a millimetre, were placed, one on the slab, two on the side of the beam, and one on the underside of the beam. To prevent any injury occurring to the one on the slab, it was protected by a small wooden box. The iron clamps were fixed as shown on the sketch. The deformations due either to the extension or compression of the concrete, acted on a small spring, and the results were easily read from the dials of the apparatuses.

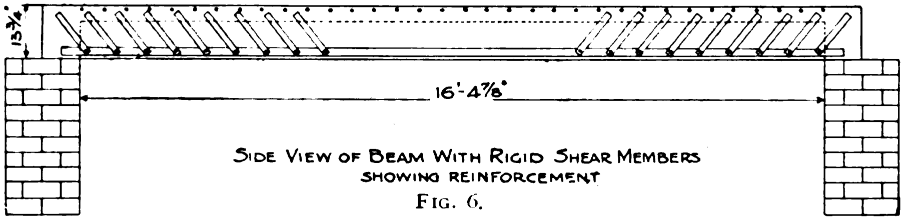


SIDE VIEW OF BEAM WITH LOOSE SHEAR MEMBERS SHOWING REINFORCEMENT

FIG. 4.

TABLE "A" TO TEST No. 1 (LOOSE STIRRUPS).

Order of loading.	Total distributed load in lb.	Deflection in inches.	Deformation in inches on a length of 19 ft. 6 in.				Observations.
			Compression A	Tension B	Tension C	Tension D	
1	4552	·08858	·002362	·002756	·0026574	·009350	—
2	9104	·21260	·005315	·006299	·0061023	·107716	—
3	13656	·35433	·008661	·009842	·010138	·026771	Cracks first noticed.
4	18208	·48031	·012008	·02992	·015157	·034448	Extension of cracks.
5	22339	Failure	·012204	·013385	·017421	—	Sudden failure.



SIDE VIEW OF BEAM WITH RIGID SHEAR MEMBERS SHOWING REINFORCEMENT

FIG. 6.

TABLE "B" TO TEST No. 2 (RIGID SHEAR MEMBERS).

Order of loading.	Total distributed load in lb.	Deflection in inches. E	Deformation in inches on length of 19 ft. 6 in.				Observations.
			Compression. A	Extension. B	Extension. C	Extension. D	
1	4657	·079	·001968	·001476	·006102	·007086	—
2	9208	·174	·004822	·003199	·012246	·013188	—
3	13865	·282	·007775	·005118	·020177	·20375	Cracks began to appear in centre.
4	19069	·412	·011023	.006988	·028346	.026918	Extension of cracks.
5	23725	more than ·669	(apparatus removed)	(apparatus removed)	.036122	(apparatus removed)	Further extension of cracks.
6	26830	(apparatus removed)	—	—	(apparatus removed)	—	Gradual failure.

Fig. 2 is a photograph showing the method of connecting up the apparatuses. *Fig.* 3. is a diagram of same. After applying each layer of cast-iron balls, the dimensions shown by the various appliances were recorded.

Test No 1.—Data where the Shear Members were Loose Stirrups.

The Beam.—The beam supported at its ends was 6 in. wide and 13¾ in. deep. The reinforcing bar was ½ in. by 2 in. On this bar were spaced sixteen stirrups, as shown in *Fig.* 4. The stirrups extended up into the slab. The percentage of the area of the reinforcement to that of the beam was ·95 per cent. The slab was 4 in. thick, reinforced with thirty-six ½ in. round rods placed at right angles to the beam. These bars were about 1½ in. from the upper surface of the concrete and about 6 in. apart.

The Test to Destruction.—The floor was uniformly loaded. The failure occurred suddenly under a test load of 22,339 lb. The beam failed by shear along an inclined plain, 4 ft. 7 in. from one end. The floor came down suddenly and rested on struts arranged to prevent a complete collapse. The results of the loadings and deflections are shown in the Table "A."

Test No. 2.—Data where the Shear Members were rigidly connected to the Main Tension Member.

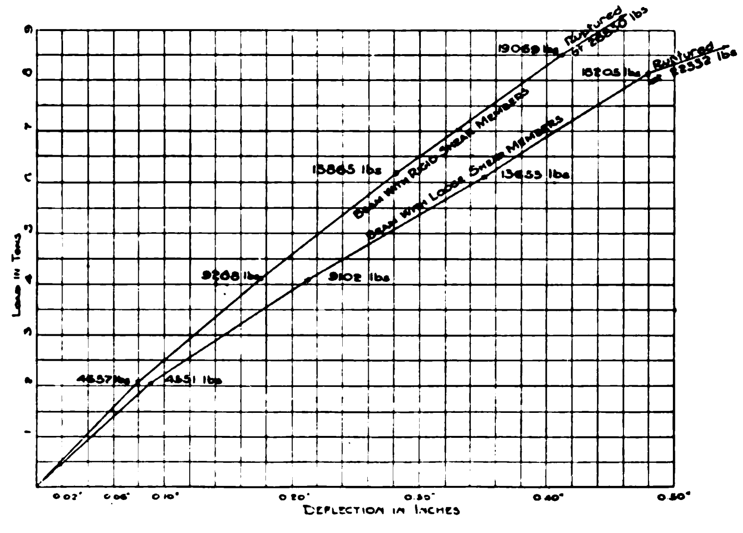
The Beam.—All the dimensions and the amount of reinforcement were the same as in the preceding case. The shear members were riveted to the flat iron bar, and were inclined at an angle of 45 deg., as shown in *Fig.* 6. The reinforcement in both cases consisted of metal of the same tensile strength, as both bars were cut from one piece.

The Test to Destruction.—The loading was carried on to the ultimate destruction of the beam, which took place when 26,839 lb. were placed on the slab. At this point cracks occurred at the centre of the beam and the deflection was very great. The floor settled until it nearly rested on the struts which were placed to catch it. At this point the loading was discontinued, although the metal had not been severed. This was done to prevent any injury to the apparatus. A photograph of this failure is shown in *Fig. 7*, and the results of the loadings and deflections are shown in Table "B."

Some Notes.

As far as we can make out the beam reinforced with the plain rod, whereon the diagonal members were riveted, carried a load about 21 per cent. in excess of the beam reinforced with the plain bar and loose stirrups. The latter failed by shear, the failure being sudden, and seeming to have occurred with a little warning. The failure of the former was apparently a very gradual one, with ample warning given by the excessive deflection. When the bars of both beams were exposed it was noticed that the loose stirrups in the one case had slipped along the bar wherever a crack occurred in the beam. In the other, all the stirrups remained in their original position.

A diagram is presented illustrating the results of these two tests.



LAWS, RULES, AND REGULATIONS

AT HOME AND ABROAD.

The necessity of framing special regulations for the control of buildings and constructional works of concrete and of steel is being generally recognised, and new codes of rules are being issued in different parts of the world by governments, municipalities, underwriters, and estates. Important Laws, Rules, and Regulations will be published in full or in extract under this heading, for they will not only serve as a guide to those who assist in the preparation of such measures, but also to those engineers and architects who, in the absence of regulations, are anxious to safeguard the interests of their employers by specifying their work to meet the eventualities of time or unusual strain.—ED.

PROPOSED RULES FOR REINFORCED CONCRETE IN BUILDINGS.

Extract from the American Fire Office Proposals.

•The term "reinforced concrete" or "concrete-steel" in this section shall be understood to mean an approved concrete mixture reinforced by steel of any shape so combined that the steel will take up the tensional stresses and assist in the resistance to shear.

The Components Generally.

Reinforced "concrete" construction may be accepted for fireproof buildings, if designed as hereinafter prescribed; provided, that the aggregate for such concrete shall be hard burned broken bricks, or terra cotta, clean furnace clinkers, entirely free of combustible matter, clean broken stone, or furnace slag, or clean gravel, together with clean siliceous sand, if sand is required to produce a close and dense mixture; and provided, further, that the minimum thickness of concrete surrounding and reinforcing members ¼ in. or less in diameter shall be 1 in.; and for members heavier than ¼ in. the minimum thickness of protecting concrete shall be four diameters, taking that diameter, in the event of bars of other than circular cross-section, which lies in the direction in which the thickness of the concrete is measured; but no protecting concrete need be more than 4 in. thick for bars of any size; and provided, further, that all columns and girders of reinforced concrete shall have at least 1 in. of material on all exposed surfaces over and above that required for structural purposes; and all beams and floor slabs shall have at least ¾ in. of such surplus material for fire-resisting purposes; but this shall not be construed as increasing the total thickness of protecting concrete as herein specified.

Centering.

Exposed metal centering or exposed metal of any kind will not be considered a factor in the strength of any part of any concrete structure, and a plaster finish applied over the metal shall not be deemed sufficient protection.

Machine Mixing.

All concrete for reinforced concrete construction whenever used in such buildings must be mixed in a machine which mixes one complete batch at a time, and entirely discharges it before another is introduced. At least 25 complete revolutions must be made at such a rate as to turn the concrete over at least once in each revolution for each batch.

Particulars Required.

Before permission to erect any concrete steel structure is issued, complete drawings and specifications shall be filed with the commissioner of buildings, showing all details of the construction, the size and position of all reinforcing rods, stirrups, etc., and giving the composition of the concrete.

Aggregates.

The concrete shall be mixed in the proportions of 1 of cement, 2 of sand, and 4 of other aggregates as before provided; or the proportions may be such that the resistance of the concrete to crushing shall not be less than 2,000 lb. per square inch after hardening for 28 days, but for reinforced or plain concrete columns the mixture shall not be leaner than 1 part of cement, 2 of sand, and 5 of the coarser aggregate in any case. The tests to determine this value must be made under the direction of the commissioner of buildings. The concrete used in concrete-steel construction must be what is usually known as a "wet mixture."

Portland Cements.

Only high grade Portland cements shall be permitted in reinforced concrete or concrete steel constructed buildings. Such cements, when tested heat, shall, after one day in air, develop a tensile strength of at least 300 lb. per square inch; and after one day in air and six days in water shall develop a tensile strength of at least 500 lb. per square inch; and after one day in air and 27 days in water shall develop a tensile strength of at least 600 lb. per square inch. Other tests, as to fitness, constancy or volume, etc., made in accordance with the standard method prescribed by the American Society of Civil Engineers, may, from time to time, be prescribed by the commissioners of buildings.

Sand.

The sand to be used must be clean, sharp grit, free from loam or dirt, and shall pass through a ¾ in. ring, or good gravel may be used in the same proportion as broken stone, or broken hard bricks, or terra-cotta, or furnace slag, or hard clean clinkers may be used.

Design.

Concrete steel shall be designed in accordance with the following assumptions and requirements :—

(1) The adhesion between the concrete and the steel is sufficient to make the two materials at least equal to the unit shearing strength of concrete.

(2) The design shall be based on the assumption of a load four times as great as the total working load (ordinary dead load plus ordinary live loads) producing a stress in the steel equal to the elastic limit and a stress in the concrete equal to 2,000 lb. per square inch.

(3) The modulus of elasticity of concrete at 2,000 lb. per square inch is equal to 1-18 of the modulus of elasticity of steel.

(4) The steel takes all the tensile stress.

(5) The stress-strain curve of concrete in compression, when the stress in the extreme fibre is 2,000 lb. per square inch, may be assumed.

(*a*) As a straight line.

(*b*) As a parabola with its axis vertical and its vertex on the neutral axis of the beam, girder or slab, or

(*c*) As an empirical curve with an area one-quarter greater than if it were a straight line, and with its centre of gravity at the same height as that of the parabolic area assumed in (*b*).

(6) The assumption belonging to the common theory of flexure, where not modified by any of the foregoing, will apply.

In the design of structures involving reinforced concrete girders and beams, as well as slabs, the girders and beams shall be treated as T-beams, with a portion of the slab acting as flange, in each case. The portion of the slab so acting shall be determined by assuming that in any horizontal-plane section of the flange, the stresses are distributed as the ordinates will be a subject for special consideration by the commissioner with its axis in a longitudinal vertical plane through the centre of the rib of the T.

The shearing strength of concrete, correponding to a compressive strength of 2,000 lb. per square inch, shall be assumed at 200 lb. per square inch.

All reinforced concrete T beams must be reinforced against the shearing stress along the plane of junction of the rib and the flange. Where reinforced concrete girders carry reinforced concrete beams, the portion of the floor slab acting as flange to the girder must be reinforced with bars near the top, at right angles to the girder, to enable it to transmit local loads directly to the girder and not through the beams, thus avoiding an integration of compressive stresses due to simultaneous action as floor slab and girder flange.

Concrete indirect compression shall not be stressed, under the working load, more than 350 lb. per square inch. Reinforced compression members shall be designed on the assumption that this stress in the concrete will be simultaneous with one of 6,000 lb. per square inch in the steel.

In the execution of work in the field, work must be so carried on that the ribs of all girders and beams shall be monolithic with the floor slab.

In all reinforced concrete structures, special care must be taken with the design of joints to provide against local stresses and secondary stresses due to the continuity of the structure.

In the determination of the bending moments due to the external forces, beams and girders shall be considered as simply supported at the ends, no allowance being made for continuous construction over supports. Floor plates, when constructed continuous and when provided with reinforcement at the top of plate over the supports, may be treated as continuous beams, the bending moment for uniformity distributed loads being taken at not less than $\frac{WL}{10}$; the bending moment may be taken at $\frac{WL}{20}$ in the case of square floor plates which are reinforced in both directions and supported on all sides.

When the shearing stresses developed in any part of a reinforced concrete or concrete steel constructed building exceed under the multiplied loads, the shearing strength as fixed in this section, a sufficient amount of steel shall be introduced in such a position that the deficiency in the resistance to shear is overcome.

When the safe limit of adhesion between the concrete and steel is exceeded, provision must be made for transmitting the strength of the steel to the concrete.

Concrete-steel may be used for columns in which the ratio of length to least side of diameter does not exceed twelve. The reinforcing rods must be tied together at intervals of not more than the least side or diameter of the column.

CORRESPONDENCE.

Under this heading we invite correspondence.

FICTITIOUS PORTLAND CEMENT.

SIR,—The warning conveyed in your Editorial Note on the above subject is particularly opportune at the present time, when cement is being extensively applied in reinforced concrete construction by many who have learned to regard concrete as a rough material whose constituents, proportions and preparation demand little consideration, and which is capable of enduring a large amount of ill-treatment without apparent suffering.

Civil engineers know by experience how necessary it is to safeguard themselves from imposition of the kind you describe, but architects are far too apt to leave the selection of cement in the hands of building contractors, who in turn are usually satisfied if able to procure what they believe to be Portland cement at the lowest possible prices. When concrete is merely employed as filling, as a substitute for brick in foundations, and for other purposes where local defects and irregularity of quality are not of supreme importance, the use of inferior cement may not endanger the safety of the construction. But in beams, columns, and other members of reinforced concrete, local weakness or lack of homogeneity is a source of positive danger. It cannot be too strongly emphasised that unreliable concrete is fatal to the stability of reinforced concrete construction of every description, and that inferior cement is absolutely incompatible with the permanent durability of the work generally, and the protection of the embedded metal from the destructive effects of corrosion.

W. NOBLE TWELVETREES.

London, March 20th, 1906.

SIR,—Your Editorial Note on the question of fictitious Portland cement certainly merits the closest attention from engineers, architects, contractors, and building owners.

It is, of course, well-known that it is the Belgian natural cement that is so dangerous for building work, and reinforced concrete in particular, and it may thus be of interest to know that even in Germany, a public warning has been recently issued against Belgian natural cements (*ciments naturelles*), which are being sold under the false trade description of Portland cement.

There are, fortunately, two codes in this country available under which sellers of the fictitious materials can be easily brought to book, the first dealing with questions of false pretences, and the second dealing with the taking of an undue trade advantage by the aid of false labels or descriptions. Upon notice being given to the Public Prosecutor he is also generally ready to take immediate action, apart from any question of the civil rights of aggrieved parties.

It is, indeed, regrettable that we have not some swift process at home by which the same ends could be obtained, particularly as in so many modern buildings human life is very much at stake.

OBSERVER.

Cologne, April 2nd, 1906.

A DIAGRAM FOR T-BEAMS OF REINFORCED CONCRETE.

SIR,—The diagram shown herewith is believed to be new as regards the slab lines, and is sufficiently correct for most practical purposes. The neutral axis is put at ·4h from top, h being the depth from top surface to (single) reinforcement. The stress area taken as partly parabolic, is $\frac{7}{6}$ that of a triangle, on account of E_c varying 50 per cent. between neutral axis and outside fibre. Rectangular beams, or stems of T-beams, are found on the parabolic curve per foot width of b, and the slab part of T-beams on the lines marked with slab thickness per foot width of (B — b). The areas of steel, also per foot width, are given by the radiating lines.

The slab lines are laid off from the tangent to parabola, beginning on tangent point at h=2½ t, and falling 4 per cent. below tangent at h=5 t. At 2½ t $\frac{t}{(.4)}$ the bottom of slab reaches neutral axis, as in a beam.

The lines are stopped at 5 t, because thinner slabs require calculations for shear, and because the two values diverge too much beyond; but may be ranged out farther if desired.

Example 1: Span 20 ft., total load 600 lb. per square foot, beams spaced 5 ft., slab 4 in. thick. Total moment=

600 × 5 × 20^2 × 12 ÷ 8) = 1,800,000 inch pounds. In diagram, for ⅕ M = 360,000, a beam requires 17 ins. depth; a 4 in. slab 20 ins.; try 18 ins.

18 ins. on curve = 400,000 × (say) 2 ft. = 800,000
4 in. slab = 300,000 × (5 − 2) 3 ft. = 900,000

[1,800,000 Reqd.] 1,700,000

$$\text{Require } \frac{18}{17}, \text{ or } \frac{1}{17 \times 2} = \frac{1}{34} \text{ part more depth.}$$

= 18½ ins. (depth counting twice requires half the ratio of moments.)

For steel area; 18½ ins. = 1·7 × 2 ft. = 3·4 (curve)
" = 1·3 × 3 ft. = 3·9 (slab)

7·3 sq. ins.

Example 2: Stem limited to 1 ft. wide and combined width 3 ft. used out of 5 ft. panel. Moment 1,800,000 ÷ 3=600,000 on curve gives 22 in. depth, or 27 in. for 5 in. slab.

Try depth 24 ins., curve = 700,000 × 1 ft. = 700,000
" 5 in. slab. = 525,000 × 2 ft. = 1,050,000

[1,800,000 Reqd.] 1,750,000

$$\text{Required } \frac{180}{175} = +\frac{5}{175 \times 2} = \frac{1}{70} \text{ part more} = 24\tfrac{1}{3} \text{ ins.}$$

Steel 24⅓ ins. (curve) = 2·2⅓ × 1 = 2·23
" " (5 in. slab) = 1·6⅔ × 2 = 3·33

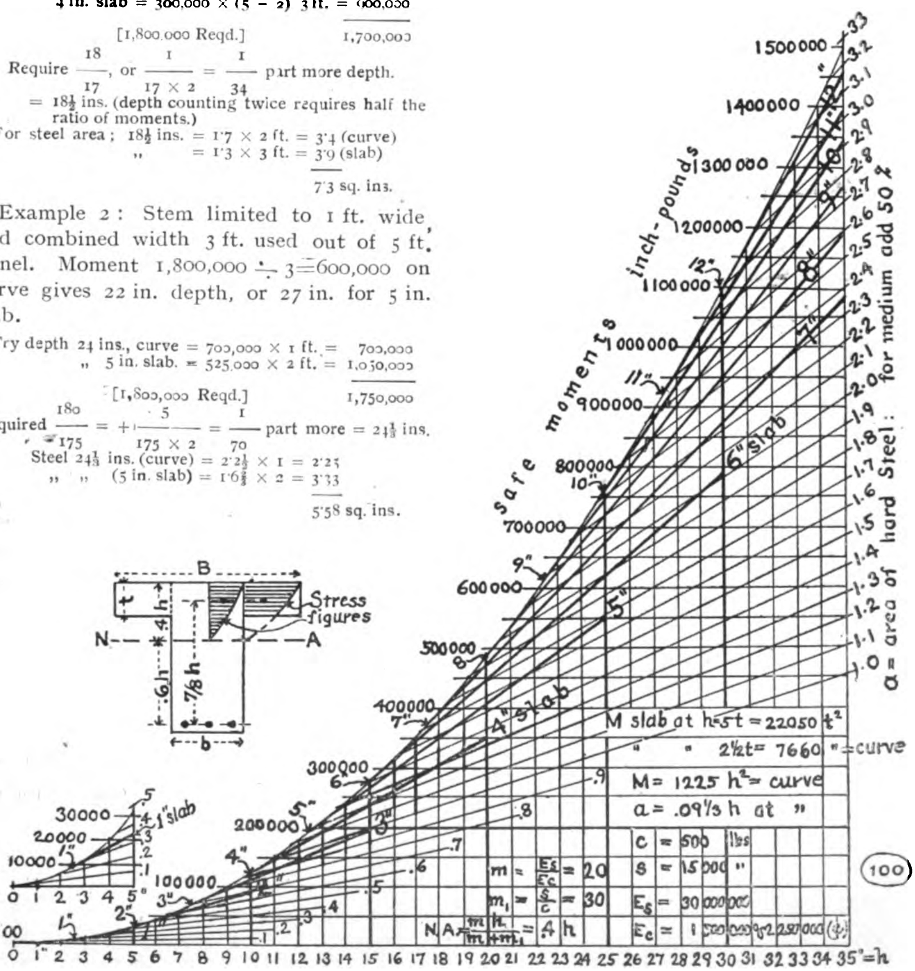
5·58 sq. ins.

Diagrams may be drawn for other constants in a similar manner; the simplest being for: Neutral axis=0.5 h. triangular stress area, tangent point at h=2 t, lower line on the tangent itself, arm ⅞h; drawing an average line a little higher, or two lines if preferred beyond 3 t. Steel area at curve=.1 h.

The rule for taking depth varying as one half the error of moment, is exact for stem, but only partly true for slab part, hence for greater accuracy calculation may be repeated with new depth.

C. E. Young.

Oregon Ave., Washington, D. C.



ARTICLES AND PAPERS

AT HOME AND ABROAD.

The following articles and papers are among the most important published at home and abroad during the first quarter of 1906 :—

I.—CONCRETE CONSTRUCTION

Articles.

Concrete in Reservoir Dams : deals with the utility of concrete for reservoir dam construction, giving full particulars of the Croton Dam, New York.—*Municipal Jrnl. and Eng., Jan.*, '06.

Sinking of Concrete Cylinders : the foundations of the railway bridge at Lend having been endangered by the deepening of the bed of the Salzach, owing to the strong current, large cylinders of freshly prepared concrete, weighing about 7 tons each, have been deposited in the river. The moist cylinders unite, forming a solid concrete mass.—*Beton u. Eisen, Jan.*, '06.

A New Concrete Covering for Timber Piles in Teredo-Infested Waters : giving ill. details of lock-joint concrete pipe armouring for timber piles, together with ill. of mould for casting the pipes which have spigot and socket joints. They are moulded in two halves, connected by scarf joints provided with keyways and secured by wooden keys, thus permitting the pipe to be clasped around the pile at any time after it has been driven. The covers are sometimes reinforced by small mesh netting, and can be applied to existing as well as to new structures. By filling the annular space with sand, an armouring is obtained which will slip downward and over any part of the pile left exposed by scour. —*Eng. News*, 4.1.06.

Shear and Adhesion in Reinforced Concrete : pointing to the conclusion that it is clearly advantageous to use diagonal reinforcement to take the shearing stresses in reinforced concrete, reference being made to the tests carried out for the Chicago, Milwaukee and St. Paul Railway Company.—*Engineering*, 5.1.06.

Rapid Construction of an Industrial Plant : having special reference to the construction of a concrete dam forming part of the work carried out at Spragues Falls for the St. Croix Paper Company. *Ill.— Eng. Rec.*, 6.1.06.

Cottages from Clinker : deals with evidence given in the course of an inquiry recently held at Liverpool for sanction to borrow a further sum for the purpose of erecting a block of concrete cottages by the Corporation. The city engineer stated he believed these buildings would prove to be the cheapest ever erected. – *Municipal Jrnl. and Eng.*, 12.1.06.

Concrete for Electrical Purposes.—*Zement u. Beton*, 15.1.05.

Heavy Concrete Retaining Walls, Illinois Central Railroad : being a description of a concrete retaining wall, 21 ft. high and 6,250 ft. long. *Ill.—Eng. Rec.*, 27.1.06.

Concrete Armament for Revetments : describing manner in which concrete is being used to protect natural rock in the revetments now being constructed by the Niagara Falls Hydraulic Power and Manufacturing Company. The protective work consists of a concrete facing from 2 ft. to 12 ft. thick, extending for a distance of 20 ft., and to a height of 150 ft.—*Water*, 15.2.06.

Concrete Building Blocks.—*Zement u. Beton.* 15.2.06, 1.3.06.

Employment of Concrete in the New Harbour Works at Hamburg.—*Deut. Bauzt.*, 21.2.06.

The Compressive Strength of Concrete.—*Beton u. Eisen, Mar.*, '06.

A Large Concrete Gas Holder Tank : describing tank constructed for the Central Union Gas Company, of New York, capable of holding 5,000,000 cubic feet of gas, the extreme diameter being 189 ft., and the depth 41 ft. 6 in. Outside the gas holder is a monolithic cylindrical exterior wall, with the total height of 41 ft. 6 in., and a thickness of 5 ft. 6 in. at the base. *Ill.– Eng. Rec.*, 3.3.06.

Papers.

Notes on Pumping and Description of Concrete Reservoir at St. Helen's Corporation Waterworks.– By J. J. Lackland, M.I.Mech.E. : reprint of a paper read before the Brit. Assoc. of Waterworks Eng. The reservoir has a capacity of 10,000,000 gallons and, with the exception of the observation houses, is built entirely of concrete. The bottom is 12 in. thick, being placed directly upon the sand rock, the pier walls carrying the roof arches are 2 ft. thick supported on arches, having 11 ft. openings, springing from 399 piers each 5 ft. by 2 ft. on plan. The roof is formed of 20 arches of 15 ft. span and 12 in. thick at the ground, the main walls being 4 in. thick at the top with a 1 : 8 batter on the inside.—*Public Health Engineer*, 10.2.06, 24.2.06, 17.3.06.

II.—REINFORCED CONCRETE CONSTRUCTION.

Articles.

Considere's Rules in the Light of Kleinlogel's Experiments. A Ostenfeld, Copenhagen.—*Beton u. Eisen, Nov.*, '05.

Comments on the above. By A. Kleinlogel.—*Jan.*, '06.

Compression Tests on Concrete with Spiral Reinforcement. By C. Bach : an elaborate series of tests carried out at the Technical High School, Stuttgart. With diagrams and photographs of the test-columns after rupture. The conclusions arrived at are discussed by M. Considere. *Beton u Eisen., Dec.*,'05, *and Jan.*, '06.

Public Baths at Colmar, Alsace. By H. Schürch, Strassburg : the basin of the swimming bath and the double roof are constructed in reinforced concrete. *Beton u. Eisen, Jan.*, '06.

Resistance of Reinforced Concrete to Shearing. By S. Zipkes, Stuttgart ; a report on shearing experiments carried out at the Technical High School, Stuttgart, on concrete blocks, with and without reinforcement.—*Beton u. Eisen, Jan.*, '06.

Some Calculations. By N. de Tedesco.—*Le Ciment, Jan.*, '06.

The Collapse of Reinforced Concrete Floors in New York : an account of the failure on December 30th in New York of the floors in a five-story building. —*Eng. Rec.*, 6.1.06.

A Reinforced Concrete Shoe Factory in Brooklyn : describing construction of four additional stories and basement to a Brooklyn factory, the floors and roof, being of reinforced concrete. *Ill.– Eng. Rec.*, 6.1.06.

Reinforced Concrete Work in India : describing mills erected in Bombay, the walls being constructed of stone and the roof and columns entirely of reinforced concrete. Numerous ills. show the work in course of erection by native workmen.—*Bldrs. Jrnl.*, 10.1.06.

Discussion of the above Tests. By Prof. Mörsch, Zurich.—*Deut. Bauzeitung*, 10.1.06.

New Premises, Newcastle-on-Tyne : describing a block of offices built at Newcastle-on-Tyne for Messrs. Milburn. The structure is steel framed throughout, and stands upon a raft of expanded steel and concrete 3 ft. in thickness. *Ill.—Building News*, 12.1.06.

Fire Resistance of Reinforced Concrete.– *Engineering* 12.1.06.

Fire Resistance of Reinforced Concrete : discussing the results of tests conducted upon a floor of reinforced hollow beams on the Visintini system, of tests reported in the Jn. of the R.I.B.A., and of tests undertaken by Professor Woolson upon a Hennebique floor for the New York City authorities. The ills. include important interior views of the Fidelity and Guarantee buildings, Baltimore, after the great fire of 1904, and of the Hennebique floor after being tested.—*Engineering*, 12.1.06.

Concrete-Steel Chimney Construction : giving particulars of a reinforced concrete chimney stack at Los Angeles, Cal., for the Pacific Electric Railway.—*Bldg. Wrld.*, 13.1.06.

Reinforced Concrete Factories for the Bush Terminal : describing large shipping plant in New York Bay, including twenty-four 50 ft. by 150 ft. eight-story warehouses. *Ill.—Eng. Rec.*, 13.1.06.

Reinforced Concrete Construction—*Continued.*

Reinforced Concrete Water Tower at Bordentown, N.J. *Ill.—Eng. Rec.*, 13.1.06.

Recent Improvements in Piles: showing the extent to which concrete and reinforced concrete are superseding timber piles. *Ill.—Engineer*, 19.1.06.

Reinforced Concrete in Egypt: description of tests carried out on the floors of a railway station at Cairo, including shock tests, a weight of 1,045 kg. being allowed to fall 20 times from a height of 2·55 metres.—*Le Béton Armé, Feb.*, '06.

Hollow Floors in Reinforced Concrete. By A. Maciachini: the floors are built up of interlocking hollow blocks. The method of calculation is described.—*Le Ciment, Feb.*, '06.

A Large Portland Cement Plant at Bath, Pa.: describing works, covering about 4 acres, designed for an output of 2,500 barrels a day. They comprise a compact group of concrete and steel buildings, the extensive use of concrete being regarded as consistent with the business in which the company is to engage. *Ill.—Engineer, Chicago*, 1.2.06.

Reinforced Concrete Reservoir at Fort Meade: describing reinforced concrete reservoir capable of holding 500,000 gallons of water. *Ill.—Eng. Rec.*, 10.2.06.

Railway Sleepers in Reinforced Concrete. By Tiemann: a description of several systems now in use or proposed.—*Zement u. Beton*, 15.2.06.

Concrete Buildings in the United States (II.): dealing with some typical examples of reinforced concrete buildings. *Ill.—Engineer*, 16.2.06.

Reinforced Concrete on the Pacific Coast. By H. A. Crafts: describing a building under construction at Oregon City, 339 ft. long by 92 ft. wide by 56 ft. high. *Ill.—Scient. Am.*

Large Steel-Concrete Stack: being the largest and highest concrete chimney in the world, just erected at the Butte Reduction Works, Butte, Mont. The height of the chimney is 333 ft. 4 in. above ground level, the inside diameter being 18 ft.—*Am. Eng., March*, '06.

Grain Silo of 7,000 cubic metres capacity: a large reinforced concrete silo has been erected on soft, wet soil. *Ill.—Beton u. Eisen, Mar.*, '06.

Water Reservoir in Reinforced Concrete at Iserlohm, Westphalia. By—Baumstark, Dortmund: a high-level reservoir, with domed roof, to contain 1,000 cubic metres of water.—*Beton u. Eisen, Mar.*, '06.

The Shearing Strength of Reinforced Concrete. By S. Zipkes, Stuttgart.—*Beton u. Eisen., Mar.*, '06.

The Calculation of Sectional Areas of Reinforced Concrete Chimneys.—*Beton u. Eisen, Mar.*, '06.

Reinforced Concrete Suburban Residence Construction. By Wm. F. Tubesing: giving particulars of a dwelling-house 40 ft. by 37 ft., with a verandah 10 ft. wide, built near Ohio river, Fort Thomas.—*Eng. News*, 1.3.06.

Reinforced Concrete Dams: some useful hints on their construction. *Ill.—Eng. Times*, 1.3.06.

Warehouse in Reinforced Concrete. By S. Zipkes, Stuttgart.: with sections and detail drawings of a four-storied warehouse at Stuttgart, and details of calculations.—*Deut. Bauzt.*, 24.1.06., 7.3.06.

Reinforced Concrete Tramway Depot at Nuremberg.—*Deut. Bauzt.*, 7.3.06.

Reinforced Concrete Construction, Marlborough Hotel Annexe, Atlantic City, N.J.: description of constructional details. *Ill.—Eng. News.*, 8.3.06.

An Economical Reinforced Concrete Floor: discussing the new formulæ proposed by Captain John S. Sewell.—*Eng. Rec.*, 10.3.06.

Papers.

Ferro-Concrete Pier at Purfleet. By H. O. H. Etheridge, Stud.Inst.C.E.—*Junr. Inst. Eng.*, 26.1.06.

Notes on Reinforced Concrete: extract of paper read by J. R. Worcester, C.E., before the Boston Soc. of Archs.—*Am. Architect*, 6.1.06.

III.—STEEL CONSTRUCTION.

Articles.

Structural Steel Dams: ill. article deals with the steel dams at Ash Fork, Arizona and Redridge, Mich. The former being constructed by the Atchison Topeka and Santa Fe Railway Company, and the latter for two mining companies in Michigan. The author gives full details of the calculated stresses in these structures and various diagrams.—*Page's Weekly*, 5.1.06.

Charing Cross Roof.—Containing account of the failure, as described in the evidence given at the Coroner's inquest. Ill. with view showing the actual size of fracture.—*Engineer*, 12.1.06.

Charing Cross Disaster: with ill. showing the fracture.—*Engineering*, 12.1.06.

Concrete Bridge Piers and Pillars with Enclosed Steel Columns. By J. Rossmanith, Troppan.—*Beton u. Eisen, Mar.*, '06.

IV.—MATERIALS AND TESTS.

Articles.

Re-Tempered Mortar in Concrete Work. By Ernest McCullough: considering the advantage of using re-tempered mortar for repairing old concrete, for use with building blocks, and for making joints between old concrete surfaces and newly laid concrete.—*Eng. News*, 11.1.06.

The American Cement Industry.—Showing the great advances made in the output of cement in America, giving data and making suggestions relative to Portland, Natural, and Puzzolana cements.—*Engineering*, 12.1.06.

American Cement Industry: based upon information issued by the U.S.A. Geological Survey, and containing much interesting data on the subject.—*Engineering*, 12.1.06.

Cement Concrete for the Protection of Steel in Building.—*Bldrs. Jrnl.*, 17.1.06.

The Durability of Paints: being a report of investigations carried out by Mr. Robert Job, for the Philadelphia and Reading Railway.—*Engineering*, 19.1.06.

Influence of Calcium Aluminate on the Setting Time of Portland Cement. By Dr. Hubert Kappen: dicalcium aluminate acts as a powerful accelerator when added in fine powder to Portland cement.—*Le Ciment, Feb.*, '06.

Fire and Water Tests of Stone-Concrete and Cinder-Concrete Floors reinforced with Corrugated Bars. *Ill.—Eng. News*, 1.2.06.

Preservation of Iron and Steel.—The action of cement and plaster: dealing with various investigations carried out in America, and advocating the use of reinforced concrete.—*Bldrs. Jrnl.*, 7.2.06.

The Stability of Iron Structures: discussing Sir Benjamin Baker's evidence at the Charing Cross Coroner's inquiry.—*Bldrs. Jrnl.*, 7.2.06.

Concrete Blocks for Harbour Works: referring to the new type of hollow concrete block under consideration by the Natal Government. This block is a rectangular shell of concrete, without top or bottom, having dovetails at its sides and ends, the size of each block being 10 ft. by 5 ft., and the weight about 6 tons.—*Water* 15.2.06.

Results of Tests Made to Determine the Strength of Concrete when Cement is mixed with Sand, Clay and Loam in varying Proportions: an extract from report on Defences of Galveston by Capt. Edgar Jadwin, Corps of Engineers.—*Eng. News.*, 22.2.06.

Hydration of Portland Cement. By P. Rohland.—a study of the simultaneous action of two or more catalytic agents on the setting of cement.—*Zeit. Angew. Chem.*, 23.2.06.

Testing of Earthenware and Cement Pipes: a description of the apparatus and methods employed at the testing station at Gross-Lichterfelde.—*Beton u. Eisen, Mar.*, '06.

Papers.

The Rendering of Iron and Steel Non-Corrosive By Sherard Cowper-Coles. Report of a paper read before Liverpool Eng. Soc. *Ill.—Public Health Eng.*, 13.1.06.

Measuring the Volume Stability of Cements: abstract of a paper read by Dr. F. G. Donnan before the Liverpool section of the Society of Chemical Industry, describing a new apparatus and method for measuring the volume stability of cements.—*Engineer*, 2.3.06.

Materials and Tests—*Continued.*

SELECTION OF PORTLAND CEMENT FOR CONCRETE BLOCKS. By Richard K. Meade: pointing out the most requisite properties of Portland cement used for manufacturing concrete blocks.—*Rept. Eng. Rec.*, 10.2.06.

LEGAL REQUIREMENTS IN REGARD TO CONCRETE BUILDING CONSTRUCTION. By Rudolph P. Miller, M.Am.Soc.C.E. —*Rept. Eng. News.*, 25.1.06.

CONCRETE BLOCKS IN ARCHITECTURE. By Louis H. Gibson: a paper outlining the requirements to be considered.—*Nat. Assoc. Cement. Users, Jan.* 9-12.

THE RESISTANCE OF CEMENT AND CONCRETE CONSTRUCTION TO FIRE: report prepared by Mr. E. T. Cairns, chairman of special committee on Cement for Building Construction of the National Fire Protection Association, Chicago.—*Eng. News*, 1.2.06.

TESTING AND USE OF PORTLAND AND NATURAL CEMENTS. By E. S. Larned, Boston: a paper dealing with the growth of the American cement industry and giving results of a number of tests, together with tables showing the tensile strength of cement mortars.—*Nat. Assoc. Cement Users, Jan.* 9-12.

V.—CONTRACTORS PLANT.

Articles.—CEMENT BLOCKS AT THE CLAY INDUSTRIES EXHIBITION, BERLIN.—*Zement u. Beton*, 15.1.05.

VI.—SPECIAL SUBJECTS (BRIDGES).

Articles.

CONSTRUCTION OF BRIDGES IN THE 20TH CENTURY: description of a number of reinforced concrete bridges together with suggested reconstructions of the Paris bridges over the Seine, reinforced concrete arches of long span, being proposed, in order to remove the present obstacles to navigation.—*Supplement to Le Béton Armé, Jan.*, '06.

BRIDGE OVER THE ISAR AT GRUNWALD: this reinforced concrete bridge near Munich has two main arches of 70 metres span each. Details and illustrations of the construction and centering are given.—*Zement u. Beton*, 1.2.06.

THE KERKERBACH BRIDGE AT HECKHOLZHAUSEN, OBERLAHN —*Deut. Bauzt.*, 7.2.06.

THE REINFORCED CONCRETE BRIDGE AT TRINIDAD, COL.: an ill. description of the bridge constructed over the Pargatorie River, having two arch spans of 70 ft., and a clear width of 64 ft. between parapets.—*Eng. Rec.*, 10.2.06.

FERRO-CONCRETE VIADUCT AT GENNEVILLIERS, NEAR PARIS: a viaduct, constructed on the Coignet system, consists of twenty spans of 5 metres, one of 5·48 metres, and one of 19 metres. The extreme width of the viaduct is 12·62 metres, but it contracts at the ends to the widths of 7·82 metres and 5·27 metres, respectively. The viaduct carries a branch railway, which passes through a reinforced concrete store to a second reinforced concrete viaduct of 38 spans. The total length of the two viaducts is about 700 ft. *Ill.—Engineering*, 23.2.06.

THE POLLASKY REINFORCED-CONCRETE BRIDGE: an ill. account of a bridge comprising 10 spans, each of 75 ft. over the San Joaquin River, this being one of the largest reinforced concrete bridges in the United States.

DETERMINATION OF THE TURNING PRODUCED AT THE CROWN OF A THREE-HINGED BRIDGE [on removing the Centering]. By Prof. G. Ramisch, Breslau.—*Zement u. Beton*, 1.3.06.

THE DANVILLE ARCH BRIDGE OF THE CLEVELAND CINCINNATI, CHICAGO, AND ST. LOUIS RAILWAY: giving an ill. description of the construction of a double rack reinforced-concrete railroad bridge recently completed near Danville, Ill., with the total length of 330 ft. including one span of 100 ft., and two spans of 80 ft each.—*Eng. Rec.*, 3.3.06.

Owing to lack of space, the sections entitled "Industrial Associations" and "Industrial Notes" have been deferred to the next issue.—ED.

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C. Ad. 11.

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C. Ad. 27.

CONCRETE
AND
CONSTRUCTIONAL ENGINEERING

Volume I. No. 3. JULY, 1906.

EDITORIAL NOTES.

INTERNATIONAL STANDARDS FOR REINFORCED CONCRETE.

IN the article we present in our current issue by Monsieur N. de Tedesco, the Editor of *Le Ciment*, this well-known authority on reinforced concrete suggests that some international action should be taken as to the collection of data regarding this building material, and that some effort be made in the direction of international standardisation. Having regard to the many communications we have received as to the necessity of some international work of this description, we cannot but strongly advocate the preparation of some scheme for centralising the world's knowledge of reinforced concrete with the view of the preparation of a suitable summary of results and eventual standardisation.

In almost every civilised country research work is at present being carried out in respect of concrete, reinforced concrete, and its component materials, and the various national and local corporations or committees in each country are, to our knowledge, endeavouring to obtain information as to the state of affairs elsewhere, either through the medium of correspondents or consular agencies, but the results of such endeavours are all too often unsatisfactory and incomplete, and we regret to say that much of the information thus obtained is also all too frequently of an *ex parte* character.

For some body of men, representative of the technical professions of all countries, to thus collect and arrange systematically the data at present available, adding thereto from time to time as the world's knowledge progresses, would be a boon to all professional men and corporations concerned.

We would invite suggestions as to the most practical manner in which such work should be undertaken, but, in the meantime hold that it would be a suitable subject to be dealt with by the International Association for Testing Materials, who could either refer it to a special sub-committee or perhaps constitute a special commission to deal with the subject under its auspices. In any case, we hold that the time is now ripe for international action.

THE REINFORCED CONCRETE COMMITTEE.

Since our last issue the Reinforced Concrete Committee of the Royal Institute of British Architects has issued an interesting memorandum by Sir Henry Tanner, F.R.I.B.A., their Chairman, which gives an idea of the nature and the scope of the investigations under consideration. There is much truth in the Chairman's comment that the technical professions of Great Britain have been somewhat reluctant and conservative in the application of reinforced concrete, and that certain of our building regulations unfortunately still militate against the general application of this form of construction. It is also all too true that, owing to the fact that no representative body of skilled men has so far in Britain made any pronouncement on the subject, doubts as to the utility of this modern form of construction may have arisen in the minds of many.

Summarised, the object of the Committee is apparently to inquire into the question of utility of reinforced concrete and to make a pronouncement thereon.

Now, all who have been associated with inquiries of this description must realise that to carry them out in a thorough manner, not only a considerable amount of time of the Committee's voluntary workers is required, but very considerable funds, a paid staff, and extensive laboratory accommodation.

Further, it is obvious that the inquiry must be a protracted one, and if results of permanent value are to be obtained in respect to the various matters touched upon in the memorandum, years must elapse until a final comprehensive report can be issued.

Through no fault of the Institute, such a report, when issued, will not, however have that weight with the engineering professions that it should have, owing to the lack of an official representation from the great engineering interests.

Again, the question of a general pronouncement is somewhat pressing, seeing that the position of reinforced concrete in Great Britain is already quite ten years behind that of the Continent and the United States.

Having regard to the improbability of the Reinforced Concrete Committee as now constituted being able to raise the necessary funds for the thorough research that is necessary, or for its members to give the time that is essential, and having regard to the absence of the co-operation of the engineering societies and many other interests that require careful consideration, such as those of several other Government Departments—the railway, dock and canal interests, the fire protective and fire insurance interests—we would suggest (having also regard to the pressing nature of some pronouncement) that the present Committee should limit its scope to a general recommendation as to whether the subject of reinforced concrete is of sufficient importance as to require careful research, and, if so, on what lines such research should be undertaken, and by whom. At the most a few general safeguards might be advocated to prevent the unwary from making those initial blunders which may cause loss of life.

Our own views are strongly to the effect that, whilst the Royal Institute of British Architects are to be eminently congratulated on having taken the preliminary steps in this matter, the work is essentially that of the Engineering Standards Committee in conjunction with the representatives of other bodies, on lines to be laid down, and with the aid of an additional Government grant beyond what has already been accorded to the Standards Committee.

We believe that an early pronouncement of a general character, with a few words of warning, accompanied, say, by some such recommendations as indicated regarding the question of research work, would be very highly appreciated by the technical professions generally, and particularly by the engineering professions, who, it must be remembered, are primarily concerned.

REINFORCED CONCRETE AS A FIRE RESISTANT.

As advised in our first issue would probably be the case, the subject of the fire resistance of reinforced concrete came before the International Fire Service Congress at Milan. What must, however, be of particular interest to all technical readers in this country is that this Congress passed an important resolution on the subject of the necessary safeguards to be observed in the use of this material in buildings intended to be fire resisting.

Coming as a resolution from a conference of men mainly interested in the protection of life and property, on the occasion of a congress whose members numbered fully 500 representatives from nearly every European country and included the Fire Chiefs of the capital cities of France, Germany, Austria and Italy, the resolution will no doubt have considerable weight with those who draft our future building regulations, and we are certainly of the opinion that the resolution was a wise one, and, if acted upon by our legislators, will prevent many an unnecessary building collapse on the occasion of future fires.

The resolution reads as follows :—

> " That the Congress considers that no reinforced concrete construction should be " permissible in buildings intended to be fire resisting, unless the aggregate be most " carefully selected and applied in such a manner as to give substantial protection to all " metal parts.
>
> " That it is advisable where reinforced concrete is intended to be fire resisting, that " every portion of the metal rods or bars contained therein be covered by not less than " 2 in. of concrete, the aggregate of which must be able to pass through a sieve having " a mesh of no more than 1 in. diameter, and that Portland cement of great fineness " only be used.
>
> " That where feasible all external angles should be rounded.
>
> " That any angle iron needed for mechanical protection should be held in position " independently of the concrete."

The principles of these safeguards advocated are of course not new in this country ; in fact, our Fire Offices Committee requires very similar safeguards for structures intended to be rated as fire-resisting buildings. Unfortunately, however, the necessity of these safeguards is not yet fully recognised by many engineers and architects, and there still exist specialist contractors who err on the side of economy by not protecting their metal work sufficiently.

Independent investigations with ordinary concrete and reinforced concrete floors have proved over and over again the necessity, not only of giving due protection to the metal work, but of being careful in the selection of the aggregate and the quality of the Portland cement used ; but there can be no doubt that reinforced concrete of suitable aggregate, with all metal parts duly protected, and with all external angles rounded, affords fire resistance of a high degree.

It would thus be most regrettable if, owing to economy, negligence or obstinacy, we should have a collapse of a reinforced concrete building at a fire.

THE SAN FRANCISCO FIRE.

We had hoped that the San Francisco fire would afford us some really good examples of the fire resistance of reinforced concrete under the severest possible conditions. Unfortunately, however, there was apparently no complete reinforced concrete building at San Francisco at the time of the disaster. In fact, independent reports which have reached us say that at the most two buildings in course of erection might be termed reinforced concrete framed-buildings with brick wall exteriors, and that in all other cases where reinforced concrete was applied it was simply in form of beams and floors.

In both the cases of the unfinished buildings, however, and in the case of the floors and beams referred to, reinforced concrete has certainly made an excellent showing both in respect to shock and fire resistance. Concrete as a protective to steel frame building has also again proved its value.

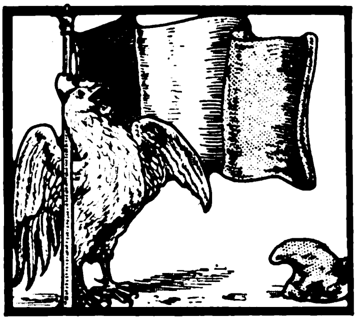
We are in the fortunate position of having before us letters of unimpeachable authority, independent of all trade interests, unanimously confirming this statement, and we hope in due course to be able to present a useful illustrated description of what actually occurred in San Francisco to buildings in which reinforced concrete or steel frame and concrete were used.

The effect of the excellent showing of concrete in conjunction with steel both in respect to the earthquake shock and fire resistance, must necessarily immediately lead to the San Francisco Building Regulations being modified in such a manner as to allow of the greater use of these materials than has been the case up to the present. We should, in fact, not be surprised to find the majority of the buildings in San Francisco becoming reinforced concrete monolithic buildings on very solid concrete foundations, and if our anticipations prove correct, this will mean a large demand for first-class Portland cement on the Pacific seaboard, towards the provision of which we anticipate Great Britain will materially contribute.

THE STANDARDS COMMITTEE ON CEMENT.

We understand that a series of meetings are again to be held by the Committee on Cement constituted by the Engineering Standards Committee, and that the first of these meetings was recently held.

There are certainly matters in the existing Standard Specification that require revision, more particularly in the direction of additional severity, and at the same time we desire to call the attention of all concerned to the fact that in the tests specified the personal element is an equation so variable and unreliable that some effort should be made to substitute for it mechanical means, as has already been the case, we believe, in some foreign countries.



The Historical Evolution of Reinforced Concrete in France.

By N. DE TEDESCO,
Ingénieur des Arts et Manufactures.
Editor of *Le Ciment.*

This article is intended to review the development of reinforced concrete in France, and to supplement the general article on the "Advent of the Concrete Age" presented in our first number. In our second number an article on reinforced concrete in the United States was intended to supplement the general article as far as work across the Atlantic was concerned. The author of this article has been in close touch with the development of reinforced concrete in France, both as a consulting engineer and also as the Editor of "Le Ciment." The issue of the article appears particularly appropriate in the year of Joseph Monier's death, a regrettable incident of March last. We congratulate the author upon the manner in which he has been able to present this article in the English language.—ED.

It is very likely that the idea occurred long ago to many architects and builders of making up for the low tensile strength of concrete by the employment of iron bars embedded in the lower portion of members, subject to transverse strain, but such innovations that remained dormant have had no real influence upon the progress of reinforced concrete construction as a branch of engineering science.

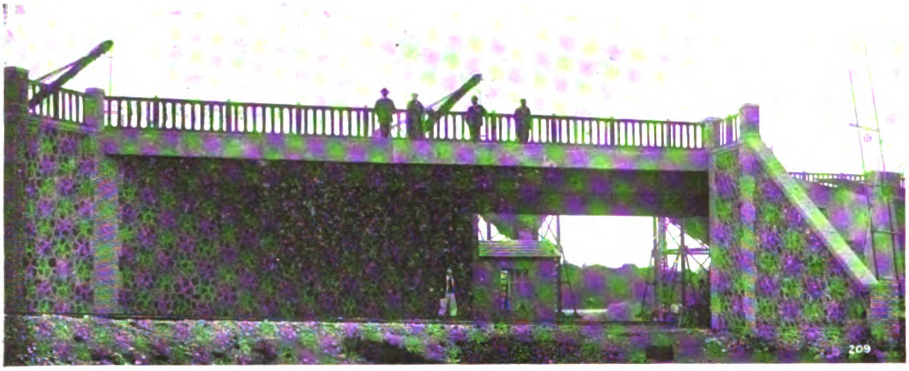
One building contractor, however, François Coignet, the inventor of moulded concrete universally known under the name of *Béton Coignet*, foresaw in an astonishing manner, half a century ago, the chief *rôle* that concrete would one day have to play in the execution of public works. Among other important works in concrete successfully carried out by François Coignet were the lighthouse of Port Said (Egypt), the high retaining walls of the Trocadero and Passy cemeteries, the church of Vesinet, near Paris, and the thirty-three miles of aqueduct "de la Vanne" (Metropolitan water supply), comprising 4½ miles of arches of 100 and 130 ft. span. In his memoirs, published in 1861, by E. Lacroix, of Paris, François Coignet has pointed out in luminous fashion all the most up-to-date applications of concrete and reinforced concrete, and has even suggested some new applications, one of the latter having reference to the improved design of roadways for the streets of great cities.

Nobody could describe better than he did at that epoch the advantages of concrete construction, easy to be carried out by unskilled labour in any required form, with materials often found in part on the site, always suitable for transport and, above all things, possessing the great advantage of being able to resist the action of fire, moisture, frost, corrosion, and, moreover, far from being liable to injury from climatic influences, of drawing up continually by contact with the circumambient air new elements of strength. On the other hand, nobody was better able to realise the one deficiency of concrete, and to discover the only means of making it good. From that knowledge to the conception of reinforced concrete there was but a step. This step Coignet took, practically in the works he carried out, and theoretically in the memoirs he wrote.

Some years later a manufacturer of gardening tools and appliances, Joseph Monier, conceived the ingenious idea of constructing concrete pots for shrubs, in the thin shells of which he introduced a network of iron bars. Such construction having given every satisfaction, as well for its strength as for its lightness, Monier applied the same principle to the design of tanks and pipes, first on a small scale, and afterwards to works of more and more importance.

EARLY APPLICATIONS.

It may be said, however, that until 1892, very few important works of reinforced concrete, or, more exactly, of "ferro-concrete," were undertaken in France, for the first applications, consisting in the use of double T-irons entirely embedded in a slab of concrete, did not constitute what is still recognised under the name of ferro-concrete. The early method of construction may be rather considered as an iron construction, reinforced by concrete. It is true that as the iron is well protected by concrete against corrosion and secondary stresses, a smaller factor of safety may be justified in the calculations; but the great dead weight of the construction takes away the benefit of the advantages originally claimed.



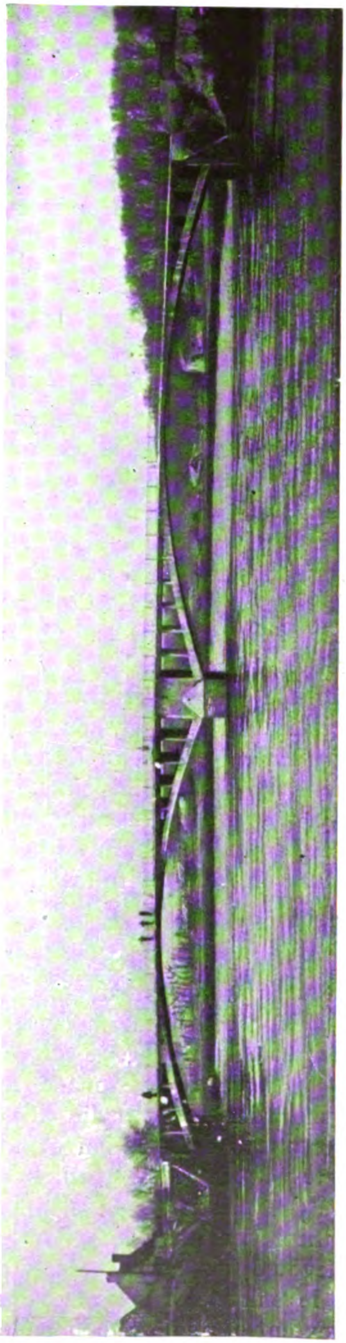
A Reinforced Concrete Skew Railway Bridge near Paris (about 60 ft. span).
Coignet System.

Moreover, the unsuitability of such structures to resist flexure may be easily understood. Let us divide ideally the heterogeneous slab into two parts, which have to resist equal stresses, one part tensile stresses and the other part compressive stresses. In the first little or no aid is afforded by the concrete; in the second, on the contrary, the assistance of concrete is relatively important. It is not rational, therefore, to provide the same section of iron and of concrete in both members. Again, considering the second factor of resistance to flexure, it is evident that the length of the arm of leverage of the internal stresses must be of importance, and the thickness of the slab representing a still greater dimension, the waste of concrete employed without benefit will be increased in large proportion.

For that reason, it is desirable to leave as much space as possible between the metal which takes the tensile stresses and the concrete which takes the compressive stresses. That is the leading principle always to be borne in mind when designing armoured concrete structures required to resist flexure, a principle that M. Edmond Coignet, the son of François Coignet, demonstrated in March, 1889, before the Société des Ingénieurs Civils de France. This desideratum was realised by building the slab as thick as possible, suppressing the major part of the concrete in tension, retaining no more than that necessary for protecting the metallic members, and connecting the compressed member, the platform, with the tension member, or rib; the connecting concrete being reinforced with ties or stirrups.

It is quite different when any given member is required to resist solely compressive stresses, a duty for which the resistance of concrete is considerable and economical. If reinforcement be used in such a case, it is not for the purpose of saving money, but space, and, besides, in order to assure the thorough distribution of the stresses.

In view of these considerations, the application of reinforced concrete to circular pipes and reservoirs, submitted to internal pressures, seems to be scarcely rational. Nevertheless, extended experience has shown that an economy of from 30 to 40 per cent. on the cost of metal structures may be secured by the construction of pipes and reservoirs in reinforced concrete, owing to the cheapness of manufacturing ferro-concrete relatively to the expensive work of riveting ironwork so as to make it watertight.



A Reinforced Concrete Bridge over the Loire (Two Arches of about 165 and 185 ft. span).

Hennebique System.

The first contractor who thoroughly appreciated the real advantages of building armoured concrete pipes on an industrial scale was Bordenave, who may be described as the creator of the practical methods of carrying out economically these special structures. Some years later another contractor, A. Bonna, introduced further improvements in that industry, chiefly with regard to pipes capable of resisting high pressures, a remarkable example of his work being the well-known siphon of Nimes, supporting a pressure of about 150 lb. per square inch. The conclusive victory of armoured concrete in its competition with metal in pipe construction is due to A. Bonna.

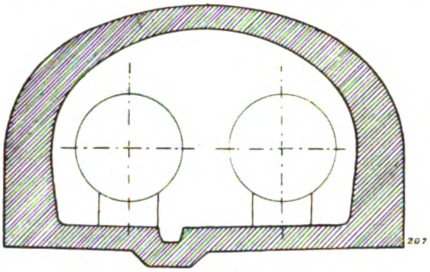


FIG. 1.

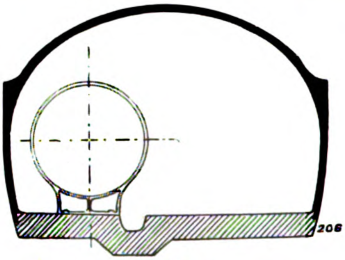


FIG. 2.

FIGS. 1 AND 2. ORDINARY TUNNEL CONSTRUCTION *versus* REINFORCED CONCRETE CONSTRUCTION.

As an impartial historian, the writer is bound to mention as one of the pioneers of reinforced concrete, P. Cottancin, whose æsthetic designs have excited much interest among architects. Cottancin makes use only of richly proportioned concrete, armoured with a special framework of steel wires, woven together for the purpose of hindering the swelling of concrete by buckling of the fibres. The arrangement of his beams, or ribs, crossing the platforms or slabs of a floor system in diagonal directions, produces a very pleasing effect, and transfers the loads at the most favourable points. Unfortunately, in spite of its real advantages, this system does not lend itself to easy calculation. The same disadvantage does not apply to the form of hooped concrete which M. A. Considère, the eminent engineer, constitutes with metal windings, whose assistance is less difficult to determine.

THE ADVENT OF REINFORCED CONCRETE.

The real aurora of the "ferro-concrete" age in France took place between 1890 and 1892. Two engineers chiefly—Edmond Coignet and François Hennebique—are the pioneers of the modern evolution in the art of building. Both, and each in his own way, have made numerous tests in order to ascertain the laws of resistance and deformation of reinforced concrete; both have endeavoured to resolve the question under all its practical and theoretical aspects, but the first has devoted his activity largely to scientific investigation, and the second to an ingenious commercial organisation to which is due the phenomenally rapid extent of reinforced concrete in the world.

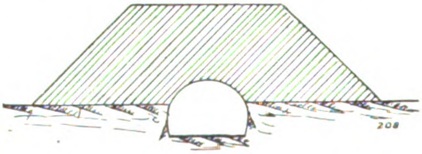
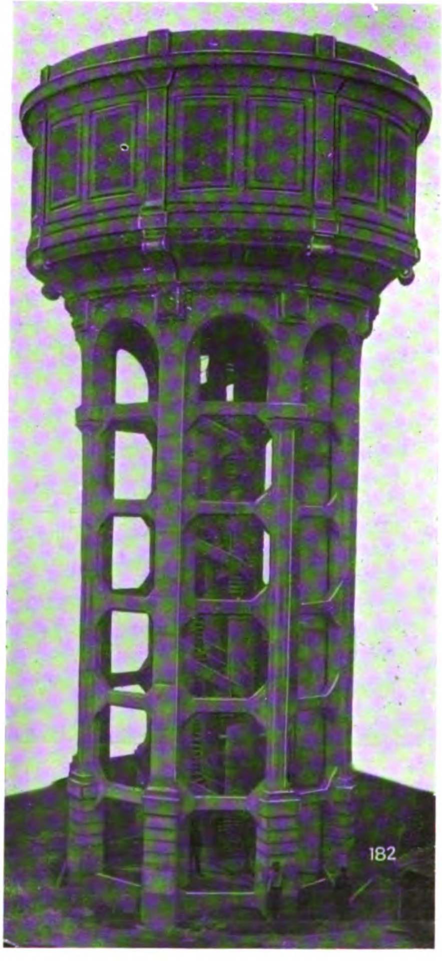


FIG. 3.

In 1892, the *Ville de Paris* having decided to establish the new system of main drainage known under the name of *Tout à l'egout*, proposed that the large conduits necessary for the conveyance of sewage to the fields of Achères should be built in stone, the works including 2,800 yards of tunnel, with a span of 17 ft. M. Ed. Coignet thereupon suggested the replacement of the masonry by reinforced concrete, in accordance with his system, promising a large saving of money and of time required for construction. *Figs.* 1 and 2 show the difference between the first design and that of M. Coignet; *Fig.* 3 illustrates the heavy load covering the tunnel.

MM. Bechman and Launay, the chief engineers to the Ville de Paris, had considerable hesitation in accepting the alternative scheme, especially when comparing the sections of the two designs and reading the proposed dimensions: 3⅛ in. of concrete and a lattice of round bars of ⅝ in. and $\frac{5}{16}$ in. diameter. The reinforced concrete structure was, however, finally adopted, and was carried out with full success; and as *Ciment* prophesied in January, 1896, that bold work and other not less interesting structures of reinforced concrete appertaining also to the *aqueduc d'Achères*, formed the starting point of numerous applications of the new material to public works.

During the same period M. Hennebique was engaged in organising his technical staff and appointing active agents in the important centres, entrusted with the selection of numerous licensees, chosen from among the most influential contractors. As the result of that ingenious organisation, it is said that from 1892 to 1899, 3,000 constructions of various kinds in reinforced concrete, to a total value of two millions sterling, had been carried out by his firm alone. Of course, a great many of these works are of little importance, but some are quite remarkable, as, for instance, the bridge of Chatellerault, with a total length of 460 ft., comprising three arches, one of 167 ft., and two of 133 ft. span.



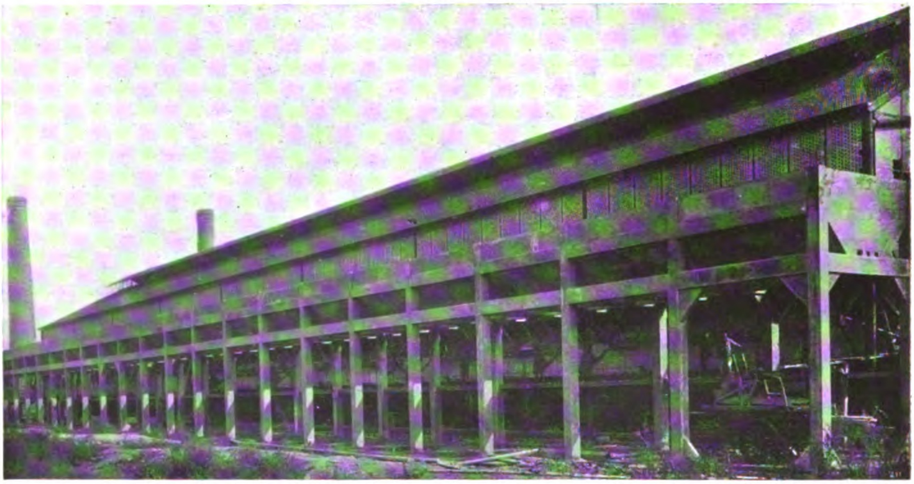
WATER TOWER NEAR PARIS.
(About 78 feet high.)
Chassin System.

The International Exhibition of Paris in 1900 served as an admirable example of the efforts made by the two leading undertakers mentioned above. It is quite superfluous to remember the success of the *Chateau d'Eau* erected by Ed. Coignet, and of other graceful palaces built by him and by Hennebique.

Both of these engineers were rewarded with a *Grand Prix*. Since that time a great many competitors have endeavoured to follow in their footsteps, and in the present day there are but few structures of importance that are not built in reinforced concrete, a material that permits almost unhoped-for savings of money and time to be effected.

RESEARCH WORK.

As already remarked, the modern method of building remained for a long time in very few hands, and nothing was to be found in literature concerning the calculation of structures constituted by two different materials. The reinforced concrete contractors were obliged to make experiments themselves in order to ascertain the most suitable proportions and arrangements of these materials for resisting a determinate load on a determinate span. As a general rule, contractors are scarcely able to undertake with advantage investigations of that kind, requiring time and accurate knowledge in mathematics. It appeared that such work would be rather the *rôle* of *Ingénieurs des Ponts et Chaussées*, and many of these, for example, Stellet, Lefort, and Rabut, attempted to co-ordinate the results of numerous tests carried out by Coignet and by Hennebique, and to deduce from them mechanical laws permitting the calculation of the elements of a given construction. That was a great mistake, which for many years stopped the progress of the theory of reinforced concrete. In fact, the mechanical properties of concrete being variable with the quality of sand or gravel, the cement used, the degree of fluidity of the mixture, the climatic influences during the hardening process, the



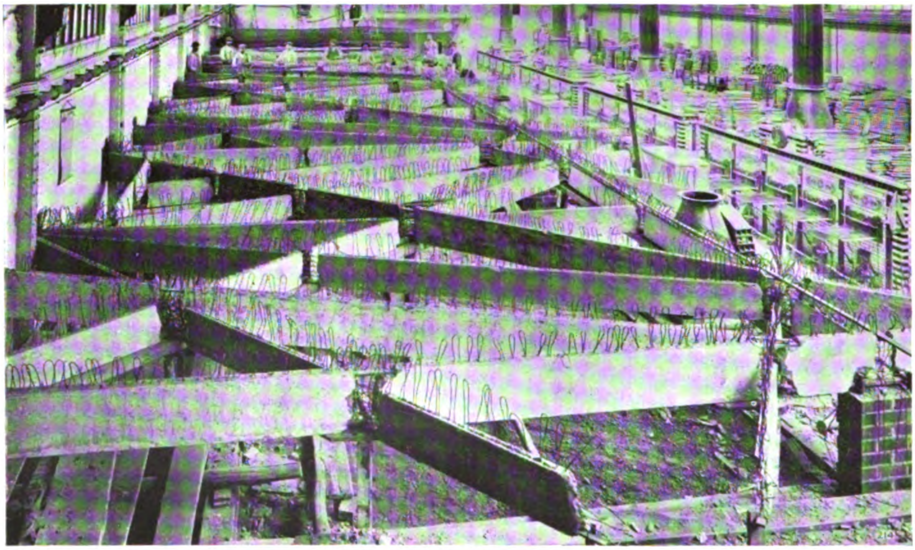
REINFORCED CONCRETE COAL BINS AT GAS WORKS, NEAR PARIS (ABOUT 412 FT. LENGTH).
Coignet System.

age, and with many other surrounding conditions, the problem was almost insoluble. It would certainly have been much wiser to look for light from numerous tests undertaken in a laboratory upon small specimens all manufactured by the same hands and under the same conditions, and to inquire successively into the effects of deformation observed for every kind of stress, one after the other; then applying to the observations the mechanical laws it would become possible to navigate in the theoretical domain, and to determine the practical co efficients in such a manner that the formula obtained would give, as a rule, the dimensions indicated by numerous experiments made on a practical scale. Such was the mode of operation adopted by M. A. Considère, first in personal investigations, and further, as the virtual manager of the works of the *Commission Ministerielle du Ciment Armé*. The same method was followed many years before by Ed. Coignet in 1893 with the collaboration of the writer, but, of course, in a less scientific manner. It was the subject of a paper read before the *Société des Ingénieurs Civils du France*, in March, 1894; this paper remained for a long time almost unnoted because it was premature, owing to the general ignorance of engineers with regard to reinforced concrete. Nevertheless, the paper was practically the expression of truth, as will be seen after the publication of the works of the above-mentioned Commission. Moreover, some ideas it contains concerning the convenience of taking into consideration the resistance of concrete to tensile stresses, appear as advances upon the general opinions actually held at the present day. It is known that M. Considère, who discovered the laws of deformation of concrete submitted to such stresses, has recognised, as a member of that Commission, the necessity of allowing this idea to crystallise for some years more in the mind of engineers. As, during that time, many thousand important constructions may be erected, the authorities desired to have easy methods for exercising their control.

REINFORCED CONCRETE VIADUCT NEAR PARIS.
Coignet System.

IMPENDING FRENCH REGULATIONS.

The French regulations have not yet been published, but it is said that they will be very liberal and have merely a provisional character, in order to leave the door open to the future advances of science. Every constructor may propose his own methods, subject to the condition that he must be able to justify them before approval. The stresses allowed must not exceed, for steel, 16,600 lb., for iron 13,280 lb., for the extreme fibres of concrete in compression 635 lb. per square inch. The last figures relate to the mixture generally used in France, viz., 400 litres of sand, 800 litres of gravel, and 300 kilogrammes of cement, or approximately five parts sand, ten parts gravel, and three parts cement in volume. For mixtures 16½ and 33 per cent. richer, 83 lb. and 166 lb. more stress per square inch are allowed, respectively.



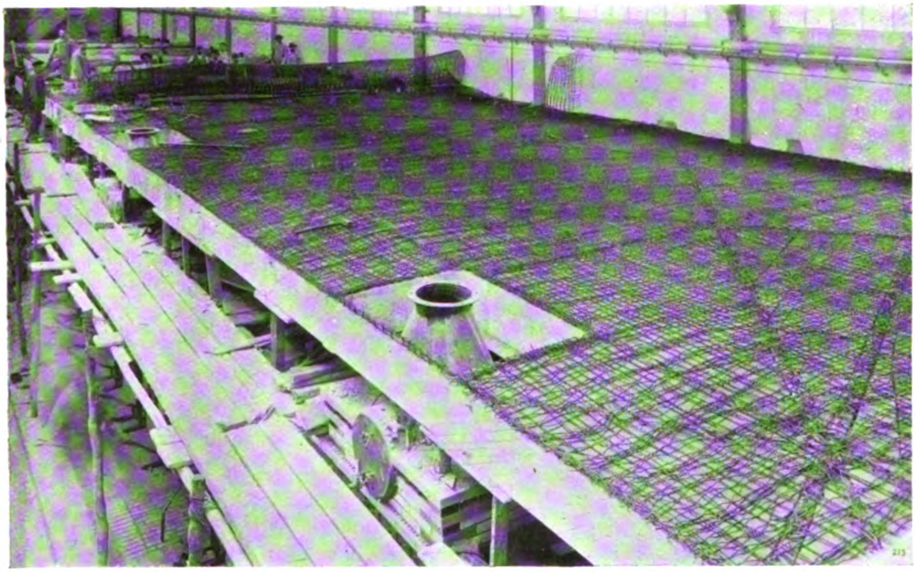
Reinforced Concrete Floor Beams in Course of Construction near Paris.
Cottancin System.

The resistance of concrete to tensile stresses is to be entirely neglected in the calculations.

The modulus of elasticity of concrete is to be considered as constant; whatever be the load; and the ratio of moduli concerning steel and concrete is to be taken equal to 15. Under these conditions the calculation of reinforced concrete becomes relatively simple, as it is possible to apply the general laws governing homogeneous bodies; it suffices to take no account of the concrete in tension, and to replace the volume of the principal armatures by a volume of concrete fifteen times greater.

In omitting the resistance of the extended concrete, the degree of safety is certainly increased and the methods of calculation are much simplified. But, on the other hand, the solution of the problem is thereby complicated and becomes quite erroneous if it is intended to determine the deformation; but it may be added that this calculation is seldom, if ever, made.

The same hypothesis of mechanical equivalence between concrete and metal amplified fifteen times in volume is applicable to the bars introduced in the compressed parts of the concrete for the purpose of increasing the resistance to compression without increasing the dead load. In other words, it would not be permissible to allow for steel in compression a working stress equal to that of steel in tension, because it results from the adherence of the two materials that the concrete enveloping the compressed bars would be submitted to stresses equal to $\frac{16600}{15}=1{,}107$ lb., instead of the permitted limit of 635 lb. per square inch. This stress corresponds to 3½ as factor of safety, and if increased to 1,107 lb. per square inch, the factor would be reduced about two.

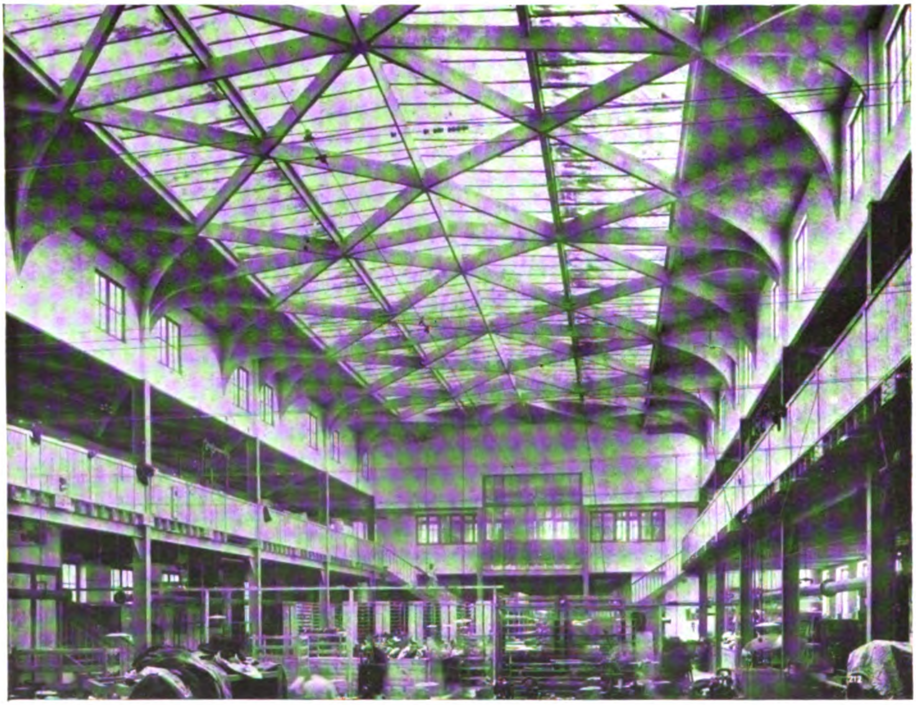


Reinforced Concrete Floor in Course of Construction.
Cottancin System.

In following this rule literally the calculated bars in compression may be found often more important than those in tension, which appears absurd. In fact, applying the same rule to pillars, nothing hinders the provision of a metal section sufficient for resisting the load without any assistance from the concrete. For instance, let us suppose that the metal section has been calculated in order to resist a load of 70 tons at the rate of 16,600 lb. per square inch, then it would suffice to embed these bars in concrete, but so little as to be negligible, to reduce the strength of the pillar as a whole to only $70 \times \frac{2}{3{\cdot}5} = 40$ tons. Such a consequence appears exaggerated, for the co-efficient of elasticity of concrete increases rapidly, as everybody knows, as soon as the stress to which it is submitted exceeds the normal rate.

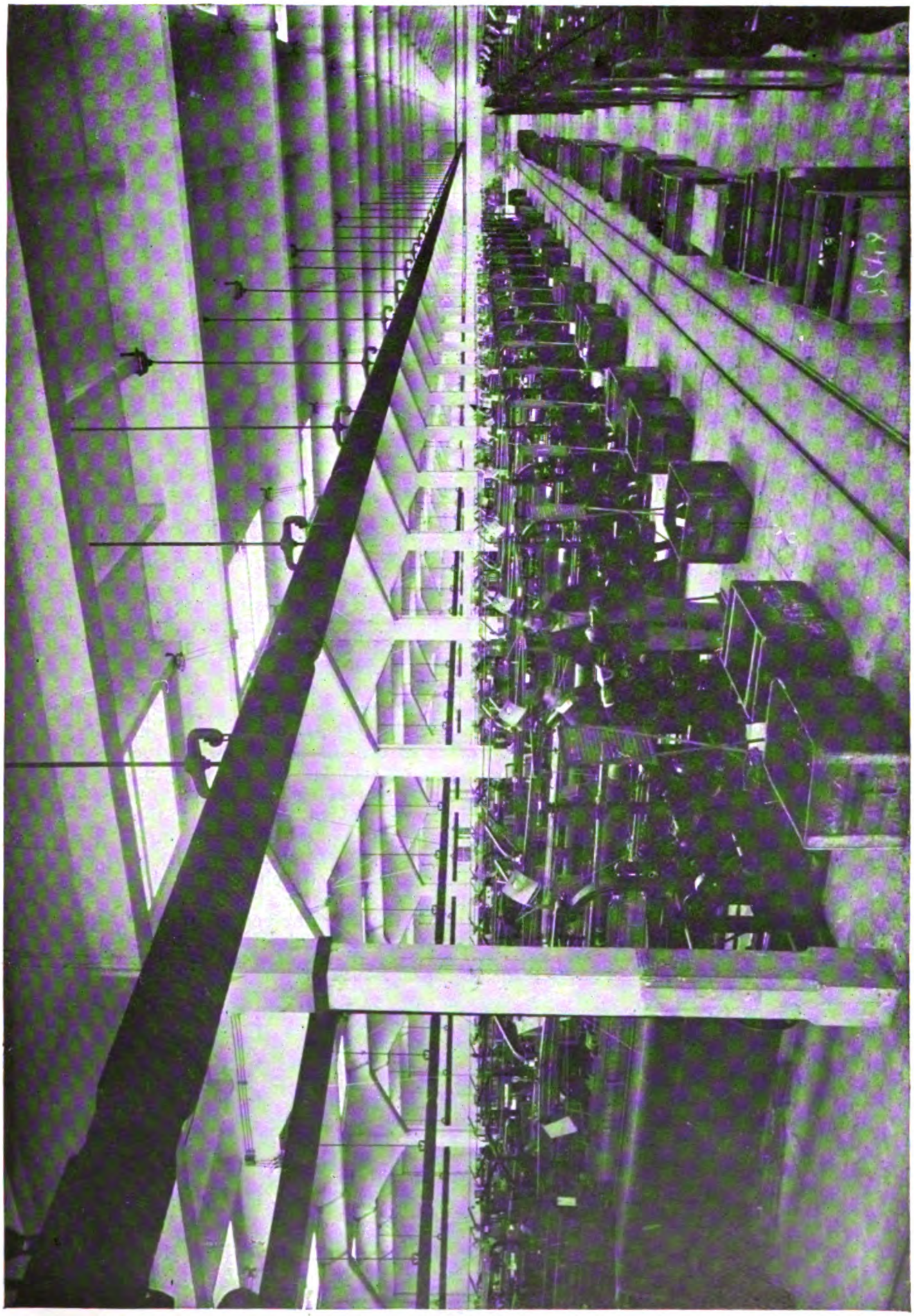
When such an anomaly results from the application of the above-mentioned hypothesis to the case of a beam, the best course is to increase the height of the beam, that is the power arm of the moment of resistance.

The shearing strength of concrete must not be taken as exceeding the tenth part of its strength to compression. Although very small, this rate is sufficient as a rule to allow slabs to resist the shearing stresses without the assistance of transverse reinforcement, the volume of concrete being considerable; but for the combination of slabs and ribs, owing to the relatively small area of concrete, ties or stirrups of steel are necessary, and their section is to be calculated for resisting the shearing stresses without taking into account the aid rendered by the concrete Such a rule seems to be too rigorous, as contractors have always admitted that concrete and the metal of the transverse reinforcements might each take half the value of the shearing stresses.



A FACTORY ROOF OF REINFORCED CONCRETE BEAMS AT PARIS.
Cottancin System.

The adhesion of concrete to the reinforcement is assumed to be equal in value to its shearing strength; as the adhesive power is comparatively small it is always necessary to ascertain whether there is any reason to fear a dangerous sliding of the bars in the mass, and to provide suitably for resisting such a tendency.



Interior of Mill at Romorantin, France (Length of Floor about 368 ft., Width, 177 ft., Spans, 44 ft.).

Hennebique System.

Briefly, the French regulations should give numerous hints for the rational design of buildings in reinforced concrete and constitute thus an excellent guide in the new branch of engineering, rather than a troublesome code of regulations. The men of science who have elaborated these rules did not forget that some builders had already created their art, both practically and theoretically, a long time ago, and they wisely decided to limit their stresses, and in availing themselves of the knowledge purchased by the leading constructors, to present the teachings of practical experience in scientific form, in order to prepare easy methods of controlling the works designed and carried out by less skilful men.

In conclusion, the writer desires to express the opinion that it is most desirable that an International Committee should be constituted, for the purpose of collecting and standardising the data relative to reinforced concrete, and the writer suggests that Great Britain might becomingly undertake the preliminary steps towards international action.

JOSEPH MONIER.

Since the above article was written we have been informed of the death of Joseph Monier, on March 13th last, in Paris, at the age of eighty-three. But few knew that the deceased was still among the living at the commencement of the year; scarcely anyone heard of his death in time to do him honour. He died almost unknown, almost forgotten, in unfortunate circumstances, whilst many of those who utilised his ideas are amongst the best known and wealthiest exponents of modern reinforced concrete construction. Here, indeed, we have another instance of the regrettable treatment all too frequently meted out to the inventor, unless his technical knowledge is supplemented by commercial knowledge, or unless he is able to find some loyal friend to further his material interests.

Joseph Monier was born December 8th, 1823, at St. Quentin-la-Poterie, Gard, France. A gardener by profession, the idea came to him to replace his wooden flower boxes by cases of cement, and finding these cement boxes brittle, constructed the cases of metal trellis, enveloping the trellis with cement mortar or cement concrete. His first patent on the subject is dated July 16th, 1867, and we believe also covers the principle of making tanks, reinforced concrete pipes, etc. Other patents followed, and, finally, the series of patents were acquired in 1880 in Germany by the firm of Wayss and Co., who scientifically developed the principles contained therein, building up a business of considerable importance.

No matter by whom and how developed, the greatest possible credit will, however, always be due to the late Joseph Monier for his initial efforts in the direction of evolving reinforced concrete much as we see it to-day.

JOSEPH MONIER, 1823—1906.

Reinforced Concrete Bridges.

I.

By W. NOBLE TWELVETREES, M.I.Mech.E.

In no Department of constructional engineering has reinforced concrete been found of greater service than in that of bridge work, and although Great Britain can only show but few examples of reinforced concrete bridges, they can be counted by hundreds on the Continent of Europe, and in the United States. In the present series of articles the author summarises the primary features of the most useful types of reinforced concrete bridges with the view of demonstrating the many forms available for the British designer.—ED.

IN no department of structural work is reinforced concrete likely to be of greater service than in bridge construction. Although once regarded with a certain amount of suspicion, the combination of concrete and steel has been very largely employed by bridge builders in almost every part of the world, and its use for this particular purpose is by no means unknown in our own country.

CHARACTERISTIC FEATURES OF DESIGN.

At first considering reinforced concrete merely as an economical substitute for timber and steel girder bridges, or for masonry arch bridges, engineers have now learned that the new material possesses qualities making possible the evolution of distinctive designs, occupying a position midway between those most suitable for steel on the one hand and masonry on the other. Still, deference to long-established custom has conduced more largely than could be desired to the retention of familiar forms, and for this reason many of the reinforced concrete bridges erected in the past have been given the outward aspect of masonry arches, and in some cases such structures have been faced with stone, so that instead of standing boldly before the world for what they really are, they masquerade in the guise of masonry bridges.

Nothing could be more opposed to the principles of true art than treatment of the kind, and nothing is more calculated to bring reinforced concrete into disfavour with architects. An even more undesirable method of treatment is the incorporation of sham details, suggestive of masonry construction to which such features are both necessary and appropriate.

Engineers are not always good judges of what is artistic, and the efforts they sometimes make to clothe construction in architectural form are rarely attended with happy results. On the other hand, when satisfied to leave the lines of a structure to reveal the purport of the design, criticism is disarmed and admiration may be compelled.

These considerations more particularly deserve attention because so many designers of reinforced concrete bridges seem to think it necessary that the finished work should closely imitate stone masonry. Of course, concrete being really an artificial stone, it is quite appropriate that some structures in reinforced concrete should be somewhat similar in appearance to structures built of natural stone, but the point is that designers ought not to strive after effects not legitimately belonging to the new material. Moreover, they should recognise the special properties of reinforced concrete, and endeavour to express them in designs that are not slavish imitations of ideas previously embodied either in stone or in steel.

ADVANTAGES OF REINFORCED CONCRETE.

The wonderful durability of a well-built masonry bridge is amply proved by many fine examples of early work, but owing to the fact that tension must be avoided in every part of a stone arch ring, the construction is heavy and its cost high. These two circumstances militate against the employment of stone in sites where the bearing power of the earth is small, and in districts where financial resources are limited. Brick, as a variety of artificial stone, possesses in a modified measure the merits and disabilities of natural stone.

Mild steel has provided a most convenient alternative to masonry, permitting the erection of bridges that are comparatively light and low in cost, and rendering possible the construction of spans that would be out of the question in stone. But steel labours under the disadvantage that it enters readily into combination with the normal and accidental constituents of the air, and so is subject to the form of decay generally described as corrosion. It is true that corrosion may be retarded by the frequent application of paint. But as no description of paint is absolutely impervious to moisture and gas, and as some kinds of paint seem to produce instead of preventing rust, the process of decay is bound to continue until piece by piece the whole structure will ultimately have to be renewed.

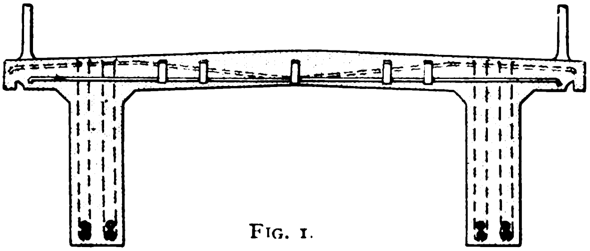


FIG. 1.

Reinforced concrete exhibit the advantages offered by stone and steel without their disadvantages. The combination possesses the durability of stone with much of the elastic strength of steel, and as bars or other forms of that metal, when buried in the concrete as reinforcement, are absolutely protected from all hostile influences, the element of decay is practically eliminated.

Concrete itself is an inexpensive product, and one that can be deposited and moulded into any required form with far less expense than that involved by the preparation and laying of stone blocks. Steel in commercial sections is also cheap, and when applied in reinforced concrete construction, the bars require none of the riveting and other operations which account for the great difference in the cost of rolled sections and built-up members. Consequently, reinforced concrete structures are less costly than those of stone or steel, to say nothing of their other recommendations.

With the object of demonstrating the extreme suitability of reinforced concrete to bridge building, some representative types of design will now be considered.

GIRDER BRIDGES.

The most simple and economical, and at the same time the most ancient, form of bridge construction is represented by the parallel beam. It is only natural to suppose that this means of communication between the opposite banks of a stream may have been suggested ages ago by the trunk of a fallen tree, and, as man has always been ready to accept hints from Nature, it would naturally occur to the early inhabitants of the world, that trees might be caused to fall by human agency at any desired points. The next stage of development would involve the felling of forest trees, and transportation of the trunks to the banks of streams for the construction of rough girder bridges, consisting of several trunks placed side by side, and covered with small branches, grass, and earth, to form a roadway. The ambition to span wider streams and rivers would naturally lead to the building of intermediate supports, so that two or more groups of trunks could be placed in series from bank to bank, and ultimately to the evolution of the framed timber bridge, of which many excellent examples remain.

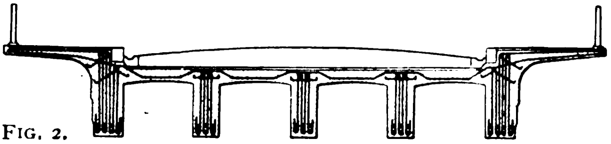
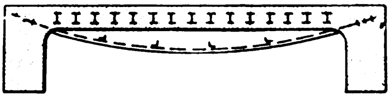


FIG. 2.

But the girder bridge in an extremely simple form is still used in the present day for crossing small watercourses, and for connecting the separate buildings of public institutions, warehouses, and factories, and for other purposes too numerous for detailed mention.

A SIMPLE GIRDER BRIDGE.

Fig. 1 illustrates the cross-section of a simple type of girder foot bridge, consisting of two longitudinal beams and a floor plate. The beams are reinforced by longitudinal bars in the tension area and by vertical strips of steel, bent to form U-shaped loops, intended to resist shearing forces. The floor plate is reinforced in a similar manner, but the upper bars of the main reinforcement are bent upwards at each side of the bridge to provide for tensile stresses occurring in the concrete near the top surface of the cantilever projections, and of the slab just inside each main girder.



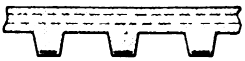


FIG. 3.

METHOD OF CALCULATING A GIRDER BRIDGE.

To design a bridge of this character is a very simple matter for any architect or engineer accustomed to the determination of bending moments, shearing forces, and the internal stresses in beams. Simple modifications of ordinary beam formulæ, such as those given in the writer's treatise on "Concrete Steel,"* will enable the user to determine the proportions of reinforced concrete beams to suit any load and span when the essential factors are inserted.

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* "Concrete Steel." Whittaker and Co., London, 1905.

ANOTHER SIMPLE GIRDER BRIDGE.

Fig. 2 is the cross-section of a reinforced concrete bridge, generally similar in construction, but larger than that illustrated in *Fig.* 1. In this case there are five longitudinal girders, connected by a floor plate, the under surface of which forms a series of flat arches between the girders and the upper surface a trough for the road material. The floor plate is extended on either hand to provide cantilever foot walks, as shown in the section.

This type of construction is very suitable for highway bridges of moderate span, the example represented in *Fig.* 2 having three spans, two of 24 ft. 6 in., and a centre span of about 46 ft.

THE MOLLER TYPE OF DESIGN.

Fig. 3 is a diagram representing the Möller type of girder bridge, very popular in Germany, the top drawing being a longitudinal section and the bottom one a transverse section. The reinforcement of the longitudinal ribs consists of a flat plate curved to suit the contour of the under surface, the plate being anchored at each end. The floor platform is reinforced by I-bars disposed transversely to the longitudinal axis of the bridge. So far as the ribs are concerned the design is good, for the curve can be made to accord with the diagram of bending moments. But the adoption of I-bars in the floor plate inevitably leads to waste of steel, as the upper flanges of the bars in the compression area are not required, and the webs passing through the neutral axis of the connection are of very little use. The same objections apply to most types of construction in which rolled steel joists are incorporated.

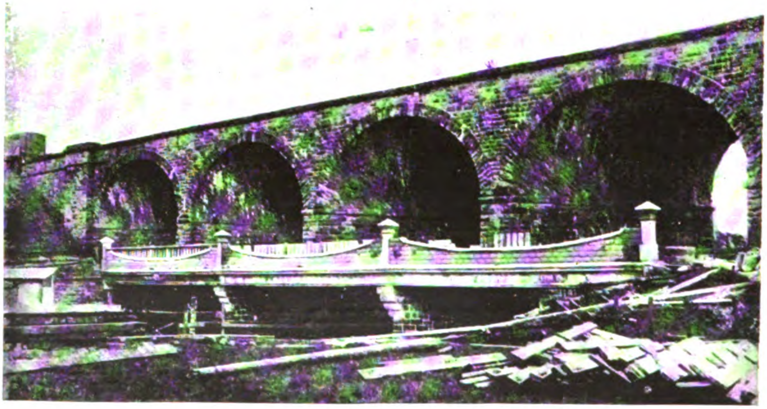


FIG. 4. REEDSMOUTH BRIDGE, NORTHUMBERLAND.

REEDSMOUTH BRIDGE, NORTHUMBERLAND.

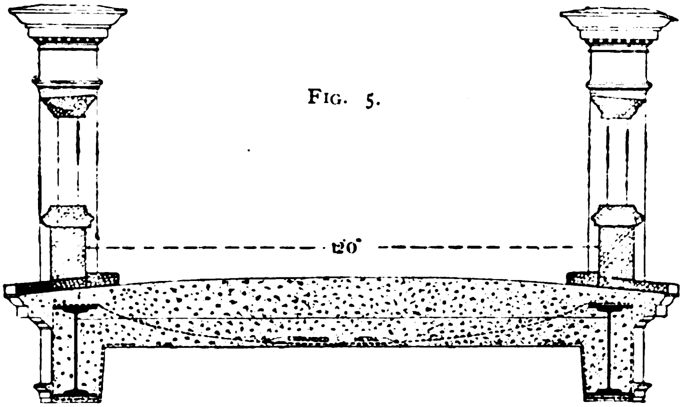
Expanded metal is a material which lends itself admirably to the purposes of bridge building, and as an example the writer takes the bridge over the River Reed at Reedsmouth. This structure was designed and built for the Bellingham Rural District Council by Mr. John Rule, of Sunderland, whose tender was some 15 per cent. lower than that of the lowest for a steel girder bridge.

The construction is of simple character, and quite suitable for the requirements of small country districts where limitation of capital expenditure is a matter of considerable importance.

The bridge includes three girder spans, each of 43 ft., as illustrated in *Fig.* 4, where, however, the new structure is somewhat dwarfed by the high railway viaduct in the background. The roadway is 12 ft. wide between the parapets and the platform slab, 14 ft. wide over all, the total length being 136 ft. from end to end.

Fig. 5 is a cross section of the bridge, and the general construction will be made clear by the following description. The floor slab is supported by longitudinal girders, each consisting of a rolled steel joist with one extra flange plate at top and bottom, and encased in concrete. Expanded steel is bent so as to pass from the inner side of one girder under the bottom, up the outer side, over the top, and then through transverse joists to the opposite girder, around which it is bent in the manner already described. The sheets of expanded steel passing through the concrete are bent to a curve approximately corresponding with the diagram of bending moments, and, as the concrete in the girders and slab is monolithic, the whole construction really constitutes a ribbed girder. The platform slab is also reinforced with expanded metal as in an ordinary floor, and steel rods of small diameter run the whole length of the bridge, so that all parts of the concrete in tension are adequately reinforced.

FIG. 5.



Although not entirely in conformance with the principles of reinforced concrete design, the Reedsmouth bridge undoubtedly represents a thoroughly serviceable and economical type of construction.

BURLINGTON STREET BRIDGE, LIVERPOOL.

Fig. 6 is reproduced from a photograph of the new bridge over the Leeds and Liverpool Canal, Burlington-street, Liverpool. The former bridge was a masonry arch of 18 ft. span, with a width of 28 ft. between the parapets. To provide more adequately for street traffic, and at the same time to afford space for widening the canal channel, the city engineer of Liverpool, Mr. John A. Brodie, M.Inst.C.E., designed the new bridge with a span of 50 ft., a clear headway of 11 ft., and a width of 55 ft. between the parapets, and decided to employ reinforced concrete on the Hennebique system for the whole of the work. The abutments are founded on reinforced concrete piles and sheet piles, and the span consists of reinforced concrete decking 24 in. thick at ends, and 20 in. thick at the centre. In order to minimise interference with traffic, one half of the bridge was built at a time. The first half was tested in January, 1905, the test load consisting of a traction engine weighing 18 tons, and a heavy lorry loaded with 35 tons of iron, on a wheel base of 10 ft., by 7 ft. 6 in. On the 4th of June, the second half of the bridge was tested by an 18 ton traction engine, drawing two lorries, each with a load of 25 tons, and, with the object of obtaining data as to vibration, the engine was afterwards driven at full speed across the bridge.

SUTTON DRAIN BRIDGE, HULL.

Another substantial structure of similar type is illustrated in *Fig.* 7, which is from a photograph of the Sutton Drain Bridge, Hull, built in Hennebique reinforced concrete from the designs of Mr. A. E. White, M.Inst.C.E., the city engineer.

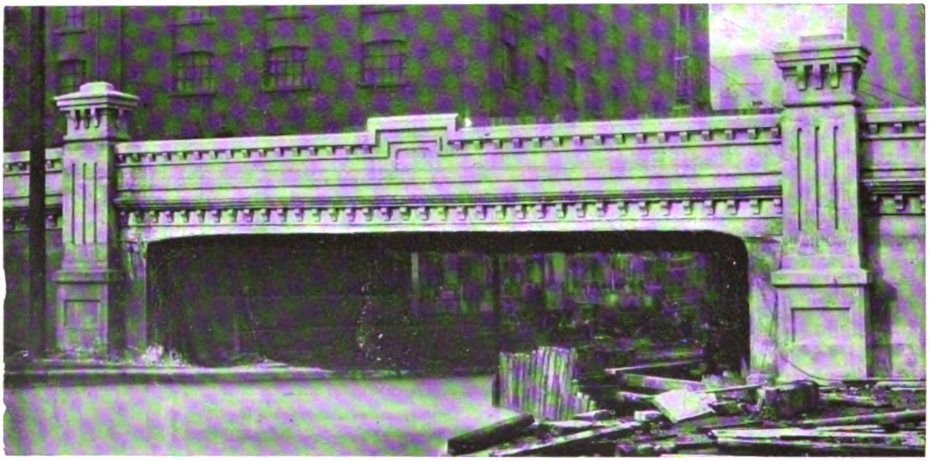


FIG. 6. BURLINGTON BRIDGE, LIVERPOOL.

Neither of the foregoing are to be regarded as imposing engineering works, but they serve the purpose of demonstrating in a practical and perfectly satisfactory manner the suitability of reinforced concrete for bridges intended to carry the heavy traffic of manufacturing and seaport cities.

BOWSTRING GIRDER BRIDGE, PURFLEET.

By far the most interesting example of any girder bridges in this country is afforded by the bowstring girder bridge at Purfleet, built on the Hennebique system (*see Fig.* 8). It consists of a single span 59 ft. 8 in. long by 20 ft. 6 in. wide, the ends of the span being supported by four cylindrical piles of reinforced concrete. Each girder is 6 ft. deep at the centre, and consists of a top and bottom boom of octagonal section, connected by 11 vertical struts, dividing the girder into 12 panels. The main girders are connected by cross girders at each end and by a ribbed deck slab, these, as well as all other parts, being of reinforced concrete.

The top boom of the main girder measures 18 in. wide by 9 in. deep, and is reinforced by eight 1⅞ in. diameter steel bars in two rows of four each. The bottom boom measures 18 in. wide by 12 in. deep, and is reinforced by eight 1⅞ in. diameter steel bars, also disposed in two rows, but these bars are carried beyond the centre of the piers, so as to provide secure anchorage. In each case, flat bars bent to a U-shape are inserted for resisting shearing stresses. The two cross girders are 18 in. wide by 12 in. deep, but these dimensions are increased by the thickness of the deck slab and at one end by an additional horizontal member forming part of the adjoining jetty. The reinforcement of the cross-girder consists of eight 1 in. diameter bars in the compression area, and a series of U-bars for resisting shear. The decking consists of a 5 in. slab of reinforced concrete with 12 in. by 8 in. ribs or joists. Other details of construction are sufficiently indicated by the various drawings reproduced.

The concrete used in this structure was mixed in the proportion of one part Portland cement to four parts Thames ballast, and the construction is monolithic throughout. The total weight of the bridge is about 90 tons, and in this are included some 15 tons of steel for the purposes of reinforcement. Taking into account the weight of steel and concrete, the relative proportions of the two materials are about as 1 : 15 by bulk.

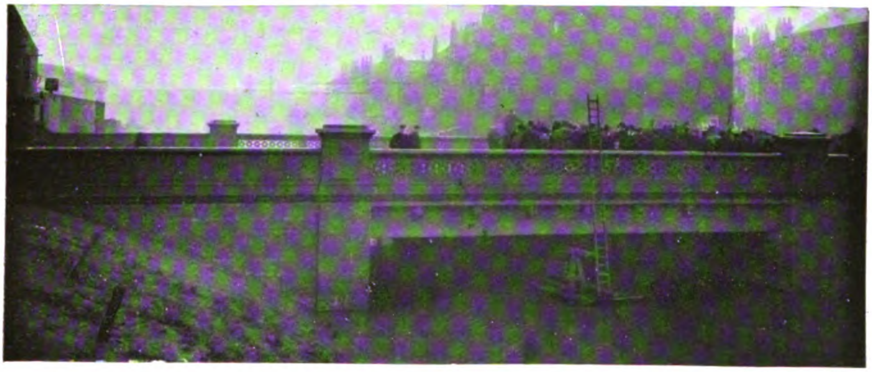


FIG. 7. SUTTON DRAIN BRIDGE, HULL.

A test of the bridge was conducted in October, 1904, when a moving load of 60 tons was passed over it, with the result that the maximum deflection was only 0·0937 in. The bridge returned to its original form immediately the load was removed, thus demonstrating the elastic qualities of the construction in a very satisfactory manner.

REINFORCED CONCRETE IN ARCH CONSTRUCTION.

The elasticity of reinforced concrete is a property rendering the material particularly suitable for arch construction, not as masonry would be used, but in accordance with the principles applied in steel structures of the kind.

Masonry arches were reinforced with metal to a certain extent long before reinforced concrete came to be regarded as a new material of construction. In early attempts to employ metal for increasing the resistance of stone arches, the voussoirs were connected at the extrados by strips of iron, providing resistance to tension at the outer joints. But as no provision was made for similar stress at the intrados, the benefit derived was of little value.

MONIER ARCHES IN EUROPE.

About 1876 arches were constructed of reinforced concrete in accordance with the Monier system, those first built having a network of iron rods at the intrados, but as this method did not provide for tensile stress at the extrados, a second system of netting was afterwards applied, sometimes extending across the arch and at others for a limited distance from the springings.

Fig. 9 illustrates, in elevation and section, the Monier bridge at Nymphemburg in Bavaria. This bridge has a span of 56·75 ft., with a rise of 6·6 ft., and a total width of 32·8 ft. The abutments are of mass concrete monolithic with the arch ring, which has two series of reinforcement.

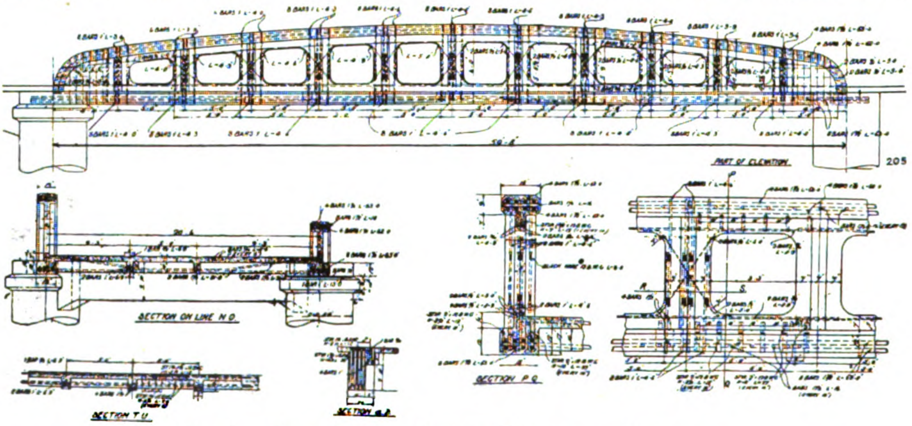


FIG. 8. BOW STRING GIRDER BRIDGE AT PURFLEET.

Fig. 10 illustrates the alternative but far less desirable method of reinforcing Monier arches, this drawing being a part section of a canal bridge at Draulitten.

So extensively has the Monier system been taken up by engineers that more than two hundred bridges of this type have been built in Europe since 1876.

MONIER ARCHES IN AMERICA.

The Monier arch has also been adopted to a considerable extent in the United States, and as an example of the form it has taken in that country, we select a railway bridge built in 1904 at Newark, New Jersey.

Fig. 11 contains a cross section at the crown of the arch, a half elevation and a half section of the bridge, which has a clear span of 54 ft. 3 in., and whose axis forms an angle of about 21 degrees with the axis of the street. The bridge is 35 ft. long in the line of the skew, and gives a clear headway of about 17 ft.

The structure consists of the arch span, massive abutments, and four wing walls, the abutments being founded on piles, and there are two sheets of expanded metal in the base of each abutment. The abutments are about 25 ft. long, parallel with the bridge axis, and monolithic with the arch ring, the front surfaces being battered 1 : 48, and the rear surfaces stepped up to the intersection with the extrados of the arch ring.

The arch is reinforced by two series of 1¼ in. bars embedded in the concrete about 4 in. from the upper and lower surfaces respectively. In the intrados the bars are spaced 12 in. apart at the springing line, and extend 5 ft. past the centre, so that for a length of 10 ft. at the crown the over-lapping bars are only 6 in. apart. In the extrados, the bars are 12 in. apart at the abutments, and extend 2 ft. 6 in. past the centre, thus making the spacing of the over-lapping bars 6 in. apart for a length of 5 ft. at the crown. At the haunches of the arch, auxiliary bars, each 26 ft. long, are disposed in the spaces between the main bars. Transverse bars of ¾ in. diameter, laid perpendicular to the axis of the street and spaced 2 ft. apart, are situated above and below the longitudinal reinforcement of the intrados and extrados, and the two series of transverse bars are continued from one end of the arch to the other.

Spandril walls of concrete, monolithic with the arch ring, are built for each face of the bridge, the outer faces being vertical and the inner faces battered.

The cross section in *Fig.* 11 shows the transverse reinforcement described above, and the manner in which the top bars are bent upwards for the reinforcement of the spandril wylls, the copings of which are further reinforced by a series of ¾ in. longitudinal bars.

The whole construction is monolithic, with the exception of an open expansion joint, similar to a vertical tongue and groove, between the ends of the abutments and the ends of the wing walls. The upper surface of the arch ring is covered by four alternate coats of waterproofing material, over which the haunches are filled with broken stone, earth, and gravel up to the crown. Above the level of the crown, cinders are laid to the depth of 2 ft., and upon the layer so formed is the stone ballast for the railway tracks.

It will be seen by the half longitudinal section in *Fig.* 11, that adequate provision is made for draining the filling above the haunches by means of a pipe communicating with the street drainage system.

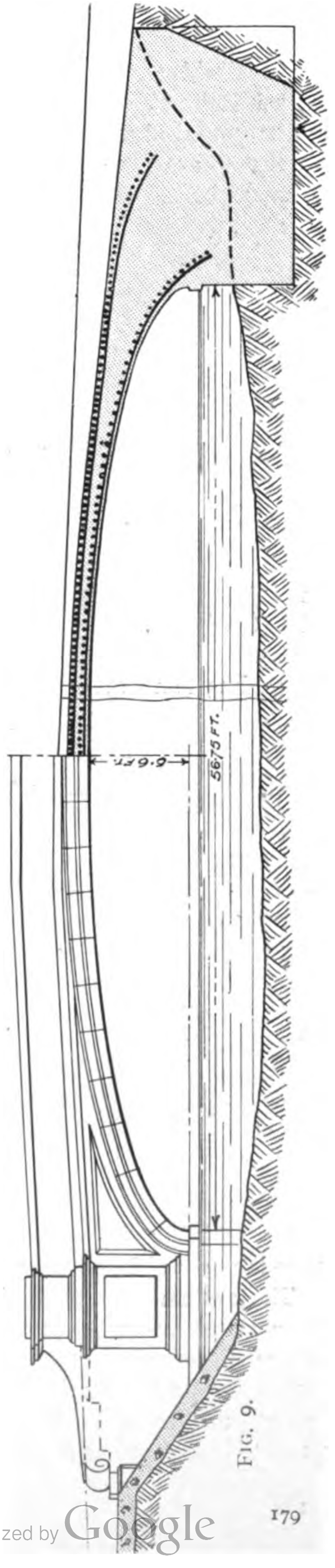


Fig. 9.

This bridge was designed by Mr. Joseph O. Osgood, chief engineer to the Central Railroad of New Jersey, and the stresses in the arch ring were computed by the graphical method of Professor W. A. Cain.

Great care was taken to design the arch ring so that the unit stresses should be approximately uniform throughout, thus permitting the quantity of material to be reduced to a minimum for the specified requirements.

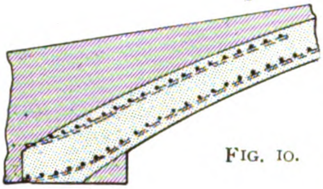


FIG. 10.

The line of pressure for dead load only, and for the dead and live loads, corresponds almost exactly with the centre line of the arch; for full dead and live loads from one abutment to the crown only, the line of pressure rises at the haunch about 4 in. above the centre line of the arch. Temperature stresses were calculated for a rise of 30 deg. Fahr. above and for a fall of 40 deg. Fahr. below from the average temperature of 60 deg. Fahr.

As determined, the maximum stresses for concrete in compression were as follows: Disregarding temperature stresses, 200 lb. per square inch, or including temperature stresses, 600 lb. per square inch; in shear, 50 lb. per square inch; and in tension, 0.

For the steel reinforcement, the maximum stresses were as follows: In tension, disregarding temperature stresses, 0; or including temperature stresses, 18,000 lb. per square inch; in compression, including temperature stresses, 5,000 lb. per square inch; and in shear, 5,000 lb. per square inch.

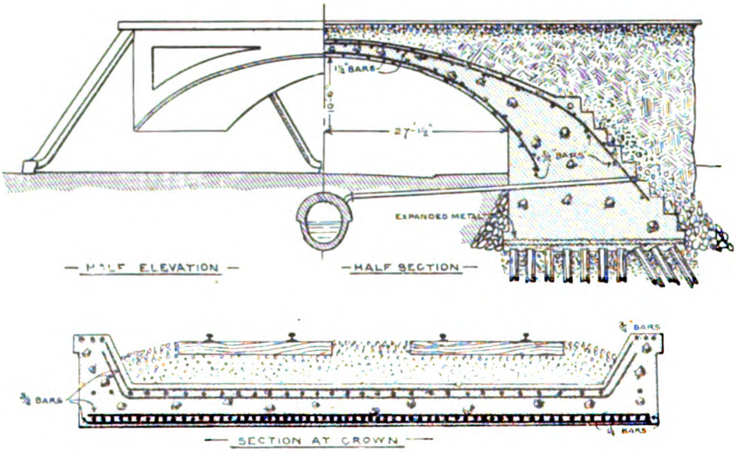


FIG. 11.

The system of construction illustrated by this bridge is not without disadvantageous features, the most important of which are—(1) That as the transverse bars are of the same diameter as those in the longitudinal direction, some of the metal is wastefully employed; and (2) that a network is not the most suitable form of reinforcement for embedding in a material like concrete, unless the aggregate is so small as to make the concrete unnecessarily expensive.

(To be continued.)

THE SETTING OF PORTLAND CEMENT.

II.

The Setting of Portland Cement from a French Aspect.

By E. CANDLOT, Paris.

To all engaged in constructional engineering, and more particularly in the application of concrete and reinforced concrete, the question of the setting of Portland cement is one of the utmost importance. Having regard to this, arrangements have been made by which a series of articles will be presented by well-known authorities at home and abroad, dealing with the question in its chemical and physical aspects, and these various articles will finally be summarised with the view of presenting the more important facts and the consensus of opinion. The attention accorded to the earlier article has encouraged us to extend our list of contributors on this subject to the leading authorities of other countries. Correspondence is invited, as a free discussion of the various arguments put forward will be welcome to all who have this subject at heart.—ED.

THE question of the setting of cement, considered from the chemical point of view, having been treated very fully in former issues of this journal by Mr. Cecil H. Desch, we shall not enter in detail into the reactions which are set up when cement in the state of powder is brought into contact with water. The theories of M. le Chatelier are generally adopted in France, and all experts agree that the setting is due to the hydration of the calcium aluminate and to that of the calcium silicate. The first of these salts is that which is concerned in all cases of rapid setting, the second, which results from the decomposition of tricalcium silicate into monocalcium silicate and calcium hydroxide, is hydrated more slowly; but whilst the calcium aluminate only assists in a feeble degree in giving resistance to the mortar, the calcium silicate is the essential element of the hardening process. In fact, cements in which calcium aluminate predominate never attain a great hardness, whilst those composed almost exclusively of calcium silicate offer the greatest resistance.

Silicious cements are always slow-setting, but, as soon as a cement contains more than three or four per cent. of alumina, rapid setting is always observed unless the calcium aluminate is neutralised by some means, the most usual being the addition of calcium sulphate.

A theoretically perfect Portland cement should set instantaneously; in fact, calcium aluminate brought into the presence of water immediately becomes hydrated, crystallises, and sets as a whole. It is quite otherwise if the aqueous solution contains dissolved calcium sulphate, calcium chloride, or even a sufficient quantity of calcium hydroxide. In that case the calcium aluminate is only very slowly hydrated.

If very finely powdered cement is mixed rapidly with pure water, and the cream thus obtained is thrown on to a filter, the proportion of alumina and lime in the filtrate is the greater, the more alumina the cement itself contained. If, instead of pure water, a solution containing 30 to 40 grains of calcium chloride per litre is used, or if the cement is mixed with finely powdered calcium sulphate, the filtrate is found to contain only traces of alumina.

It is easy to understand why twenty years ago the question of setting was relatively unimportant and hardly gave rise to difficulties. Cements were then coarsely ground, and owing either to imperfect burning or to the use of defective mixtures, almost always contained free lime. The water used in mixing thus becoming rapidly saturated with lime, the calcium aluminate could only slowly become hydrated.

Since it has been recognised that the quality of cements is greatly improved by reducing them to very fine powder, and, on the other hand, the processes of mixing and burning have been perfected, serious inconvenience has been caused by too rapid setting. It has been possible to remedy this in various ways, but it may be said that the addition of calcium sulphate (gypsum) is the most often employed. This salt, in fact, is cheap in almost all districts, and it is sufficient to add 1 to 2 per cent. of it to the cement to obtain in most cases a sufficient retardation of the setting.

The action of calcium sulphate is somewhat complex; in fact, it is only efficacious when the water used in mixing contains lime. In practice, cements always contain some hydrated lime, which rapidly dissolves in the water, and the calcium aluminate can then only slowly become hydrated; the calcium sulphate dissolves rapidly and then combines gradually and progressively with the calcium aluminate as the hydration of the latter takes place; a double salt is formed which we have been able to isolate, having the formula

$$Al_2O_3,\ 3CaO,\ 3\ (CaO,\ SO_3),\ 30H_2O.$$

These phenomena may be made clear by performing the following experiment. A cement undoubtedly containing no free lime is mixed with 1 to 2 per cent. of calcium sulphate; no retardation of setting is observed. If the cream is mixed very rapidly and poured on to a filter, no calcium sulphate is found in the filtrate, it being entirely combined with the aluminate. But if the cement is mixed with 2 to 3 °/₀ of slaked lime, the setting is considerably retarded, and on repeating the above, a considerable quantity of calcium sulphate is found in the filtrate.

This will explain to us why the setting of cement often appears so capricious, and will show us how to proceed to render it more regular.

In almost all works, cement is now produced which sets slowly when supplied to the consumer. But it sometimes happens that a month or two after the cement has been placed in store it is found, on attempting to use it, that the setting is very rapid. That is easily to be understood, since, the hydrated lime which the cement originally contained having been converted into carbonate by the action of the air, the calcium sulphate combines rapidly with the calcium aluminate, with a consequent hastening of the setting.

To render it slow, it is sufficient to add a little slaked lime at the time of using, but this method is not always easy to carry out. Another plan is simpler and can always be employed. The cement is mixed on the works with sand, which is generally moist, and it is sufficient to leave the mixture of sand and cement for 20 to 30 minutes; the water contained in the sand reacts with the cement, and when water is added for mixing, a solution of lime is at once obtained; the setting is then very slow. We have tested this method of retarding the setting by numerous experiments, and have always obtained excellent results, the resistance of the mortar is not in the least diminished.

If, on the other hand, it is desired to hasten the setting, the method to be employed is also very simple; it is sufficient to neutralise the free lime so as to allow the calcium aluminate to become hydrated rapidly. To do this the cement may be mixed with about 1 per cent. of sodium carbonate; this salt, which is very soluble, converts the free lime into carbonate, which is precipitated; the calcium aluminate can then react and bring about the setting of the mortar.

It sometimes happens that a cement appears to set extremely slowly; if calcium chloride is added to the mixing water, or if calcium sulphate is mixed with the cement, a much more rapid set is obtained. But this is merely apparent; the cement which seemed to set slowly really set very quickly, so quickly that setting began at the very moment of mixing the cement and water. The effect of the mixing operation is, in this case, to destroy the cohesion produced by the hydration of the calcium aluminate, and the setting then takes places very slowly, since it can only occur through the crystallisation of the calcium silicate. The setting is so much the slower, the greater the quantity of water that it was necessary to use in mixing the cement, and the larger the proportion of calcium hydroxide in solution. A cement thus remixed after breaking up the initial set* has quite a different appearance from one which has set normally. The latter soon gives up the excess of water, it throws off ("rejette") the water, as it is said, the mortar has the consistence of mud, it spreads itself, and only thickens when setting actually begins. "Killed" cement mortar forms a firm paste, it retains the shape given to it and does not throw off the water. If the surrounding air is dry, the mortar may become dry before setting and then it does not harden at all; and, further, if exposed to severe cold, it disintegrates completely. The use of "killed" mortar is therefore carefully to be avoided, especially when the work is to be exposed to heat or to great cold.

If the same cement receives an addition of calcium sulphate, or is mixed with a solution of calcium chloride, setting takes place normally, and as it is no longer interfered with by excess of water or of lime, it occurs within the usual period of five or six hours.

To determine the time taken by a cement to set, the Vicat needle is generally used. This apparatus is essentially composed of a needle of 1 sq. mm. section, loaded with a weight of 300 grams. When the needle can no longer completely penetrate a pat of cement 4 cm. thick, setting is said to have begun. When the needle no longer leaves a visible impression on the pat, setting is said to be complete. Really there is no beginning or end of setting. The moment at which setting appears is usually very distinct, and there is only a short interval between the cement losing its consistence and solidifying. Nearly always the cement thickens as a whole at the moment of initial set, after that it becomes harder and harder, and what it is agreed to call the end of setting is merely a certain state of hardness of the mortar. This is brought out clearly in the curve obtained with M. Périn's apparatus. This instrument, in which the needle descends automatically every 20 minutes, is so arranged that the movements of the needle are recorded. Curves are thus obtained which always indicate very clearly that the time which elapses between the moment at which the needle ceases to penetrate the pat of cement completely and that at which no appreciable penetration occurs is always very short; setting once commenced is, therefore, really complete almost at once. Certain cements when the setting has once commenced harden very quickly, others harden more slowly, but this of little importance from the practical point of view, and the moment of commencement of set is the only one of interest. It is this point, in fact, which must be known to avoid "killing" the cement, and it is very important to be sure that setting will not begin before there is time to mix and apply the mortar. As for what is termed the completion of setting, this is a factor of no real utility, and should be abolished from cement testing. The adoption of such an instrument as the Périn prisometer would lead to this result, and, in conclusion, we would express a hope that the possibility of introducing such apparatus into all laboratories for testing materials may be considered.

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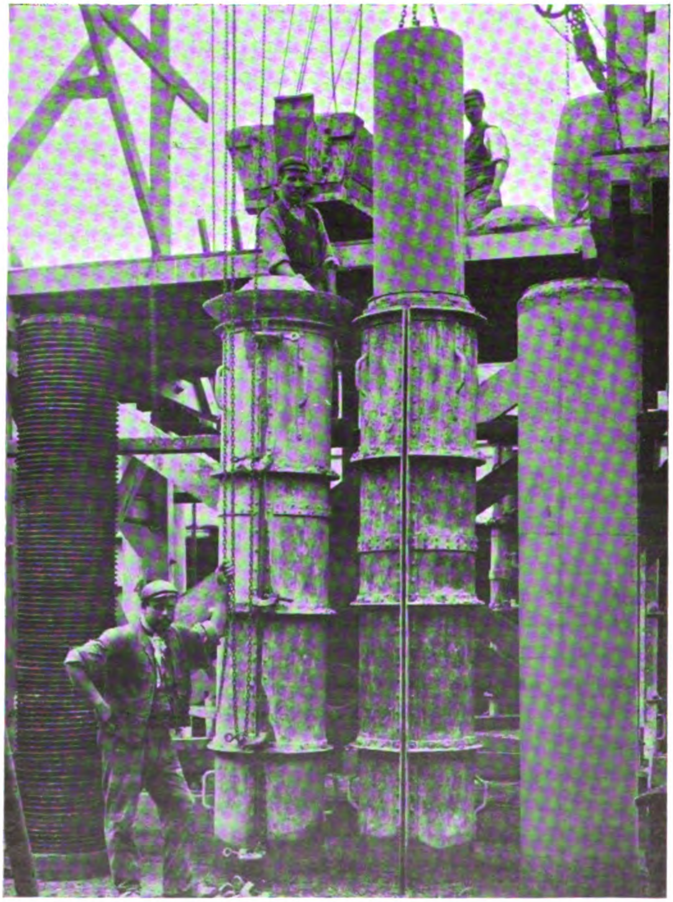
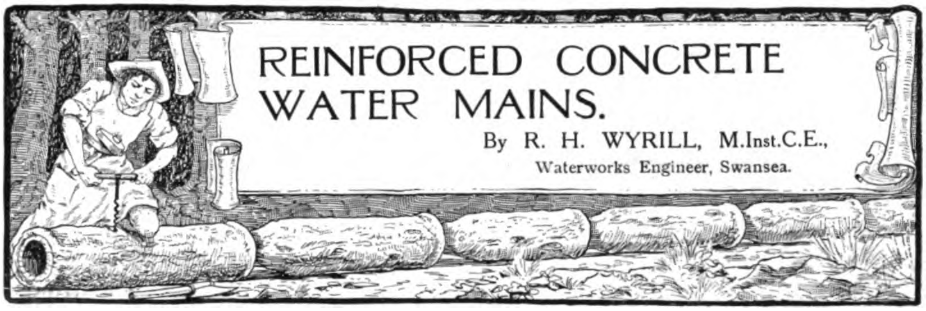
* "Killed" is the workman's term.—*Trans.*



REINFORCED CONCRETE MAINS.
FIG. 5. PIPE CASTING AT SWANSEA.



REINFORCED CONCRETE WATER MAINS.

By R. H. WYRILL, M.Inst.C.E.,
Waterworks Engineer, Swansea.

Among the new uses to which Reinforced Concrete is put, none are of greater economic importance than the application of the material to high-pressure water mains. The first cost and rapid deterioration of the metal water main is the cause of great waste of capital and also of much inconvenience to the public. Whilst in other countries the practicability and economy of the Reinforced Concrete main has long been proved, we have apparently only recently awakened to its great advantages, and it is with great pleasure that we now present an article on this important subject from the pen of the Waterworks Engineer to the Borough of Swansea, which borough should be congratulated upon the manner in which it has broken away from the general policy of conservatism in these matters in order to apply a system of construction that is economical and scientifically sound.—ED.

THE invention of reinforced concrete is generally attributed to J. Monier, who applied it in 1868. In 1861 François Coignet proposed various methods of applying reinforced concrete, but little progress appears to have been made until 1880, when the ideas of Monier were adopted in Germany, and received considerable development, more so than in France, although in 1889 Mr. Bordenare showed some reinforced concrete pipes. However, in France, in 1892, two new systems began to advance rapidly; they were those of Edmond Coignet and F. Hennebique, who really appear to have been the first to appreciate the true value of the new construction, and they undertook works of great variety and magnitude, and established branches of their business in other countries. About this time the German and Austrian engineers studied and applied the new material thoroughly, and scientific calculation of the stresses in, and the concrete designs of structures became common, and as the methods of the construction became better known the cost of the work decreased and public confidence in the new material increased with the result that to-day reinforced concrete is used far and wide in both public and private works on the continent, and its applications are innumerable. Reinforced concrete has been introduced in America comparatively few years, but during this period it has made enormous progress, and at the present time appears to be a favourite building material, particularly in its application to the construction of buildings of all classes, retaining walls, reservoirs, dams, and sewers. But one of the most important applications of reinforced concrete is in the construction of water mains to resist high pressures, and to this important question attention is here accorded.

THE PROBLEM.

As is well known, the principal duty of the metal in a water main is to withstand the tensile stress set up in it by the internal water pressure. Now, if a cast-iron main is designed simply to resist this stress, the result is that a thin cylinder of cast iron is designed which is almost too thin to cast with accuracy, and, being a metal adapted to resist compression and not tension, the result does not inspire confidence, and a certain percentage of metal is boldly added to cover irregularities in manufacture, unequal bedding in trench, water hammer, road traffic, etc., and, after all, a metal has been used which is not well adapted for its duty, but it is used almost universally, being both cheap and convenient. If a sheet steel main is designed simply to withstand the internal pressure, the result would probably be a sheet so thin as to cause doubt as to its power to resist collapse from the weight of the material filled in the trench or from road traffic; the thickness of metal is therefore increased to cover this and the weakness of joints, and this, in addition to an expensive metal, is costly, and although the body of the pipe is of an excellent material and well adapted for its duty and would give more confidence than the more uncertain cast-iron pipes, yet both of them are subject to corrosion, which will in time destroy them, the steel pipe first because it is thinner, and the rate of decay practically the same for both metals with pure water. It is therefore necessary to protect both the cast iron and the steel main from corrosion, and for this purpose the pipes are treated either by Angus Smith's process or by an application of bitumen. The writer doubts whether either of these two processes are properly carried out in usual practice, as he has frequently seen mains attacked by corrosion when only about six years old, whilst in other cases where the process has been properly carried out, he has seen mains in a good state of preservation even after twenty years use, but the latter experience is very unusual. How long this protective coating will last under the best conditions it is not possible to say, but it is probable that its effect is simply to defer the time of commencement of the attack by corrosion for a few years, and that once this sets in, little assistance is obtained by the coating. It is only during the past few years that the various valuable properties of cement in combination with steel have been realised in this country; it has been vaguely known that when the space between the outer and the inner skins of the hull of an old iron or steel ship have been filled with liquid cement and a portion of this structure is cut into after 30 or 40 years, the metal is found to be perfectly preserved; this experience of ship builders was not generally or widely known by engineers or architects, or if known has not been acted upon. It is on record that a bar of iron after being embedded in concrete for about 400 years was perfectly preserved; many other instances showing the

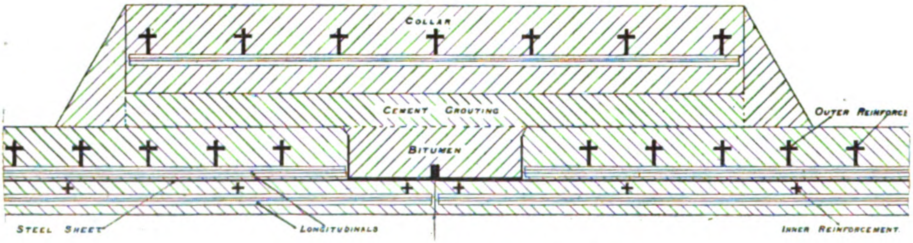


Fig. 1. Section of Main and Joints.

protection of metal by cement are known, but the experience gained appears not to have been taken advantage of until recent years.

Undoubtedly at the present time many engineers are studying the matter closely, and while the inertia of our insular adaptability is enormous, although we in this country have been much behind other nations in starting on this new industry, now that interest has been fairly roused there is no doubt that

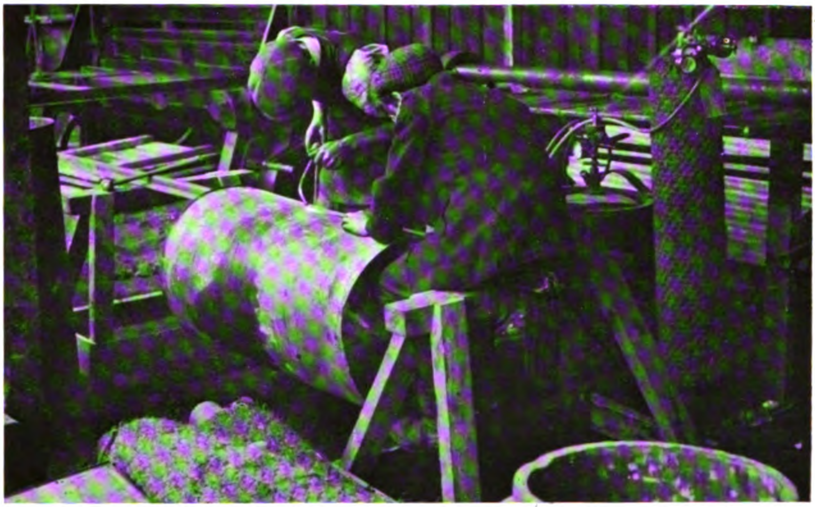


FIG. 2. WELDING STEEL SHEETS.

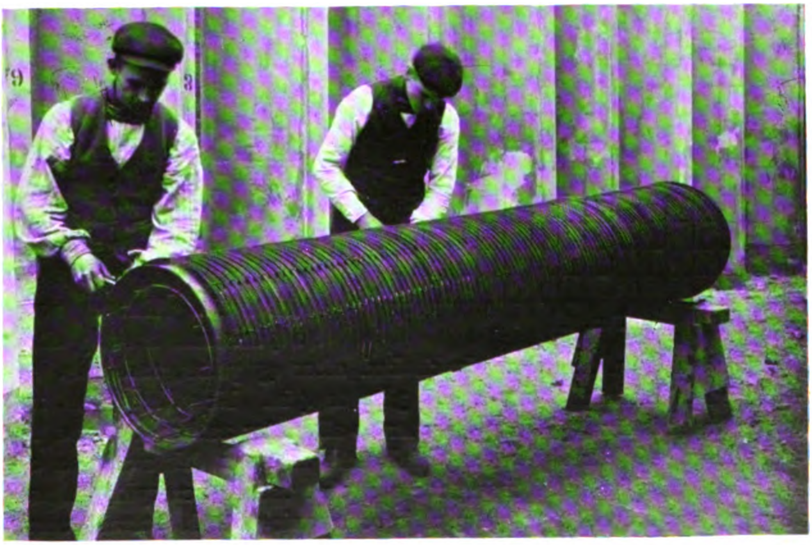


FIG. 4. APPLICATION OF EXTERNAL REINFORCEMENT.

reinforced concrete will receive ample consideration and that many important works will be carried out. Already several important works, including warehouse , many floors, and bridges, culverts, etc., have been carried out, and two tall chimneys are being taken in hand, but the most recent application is the construction of water mains for high pressures.

THE PRINCIPAL POINTS.

The main points of value in reinforced concrete as applied to the manufacture of water mains are (1) its strength, which can be made ample to deal with any stress met with ; (2) the fact, apparently widely known in these days, that if steel is well surrounded by cement the metal is absolutely protected for a very long period—certainly longer than with the best protecting dip or coating which has hitherto been applied to metal pipes. Therefore, a reinforced concrete pipe may be expected to last much longer than the metal pipes which have been used up to now, as the steel is protected from corrosion. The concrete or cement surrounding the metal whilst it is used in the first instance to protect the steel from corrosion, at the same time gives that necessary stiffening to the steel to prevent deformation from road traffic, and it also forms a better conduit for water ; it is cleaner and more wholesome, as anyone knows who has seen the interior of a cast-iron main which has been in use for, say, twenty years, and which is covered with a mass of nodules of iron rust, silt, peat, and other impurities, which gradually increase in size with age and gradually decrease the water way and usefulness of the main. The writer has seen a 4-in. main entirely choked after 35 years' use ; a 6-in. main nearly choked after 45 years, and 9-in. and 12 in. pipes reduced in internal diameter by 3 in. to 4 in. Now this interference with the flow of water is a very serious matter to all water authorities, and any means of overcoming the difficulty is very welcome, and for this reason a coating of cement seems to be an ideal lining for any pipe used for carrying water, and the advent of the reinforced concrete pipe is occasioning much interest, consequently the following description of the manufacture of a reinforced concrete water main now in progress under the writer's supervision may be of interest.

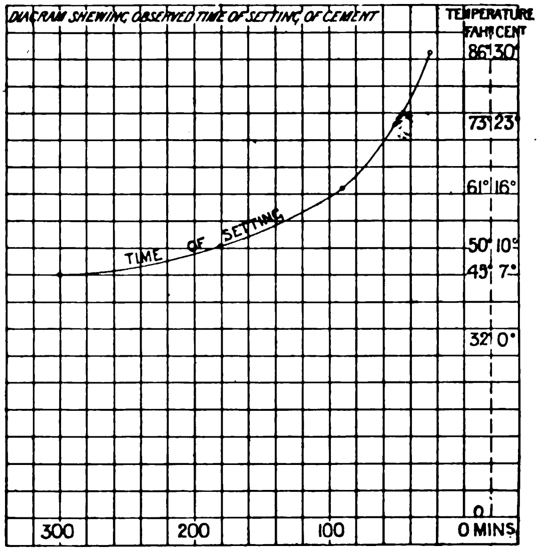


FIG. 6.

THE NEW SWANSEA REINFORCED CONCRETE MAIN.

The duty of this main is to convey water from a service reservoir in the Borough of Swansea and to connect with other water mains ; the ordinary

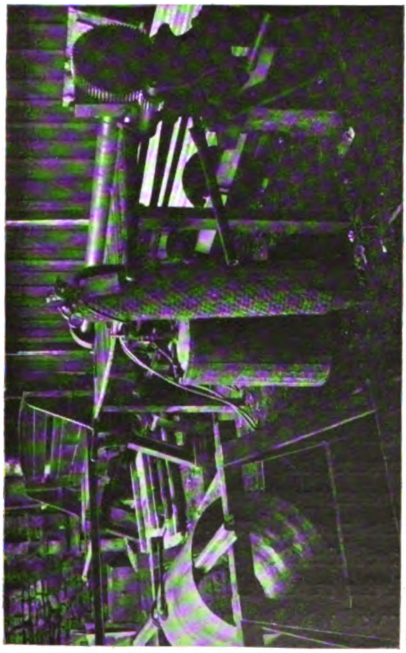


FIG. 3. APPLIANCES FOR HANDLING EDGES OF STEEL SHEETS.

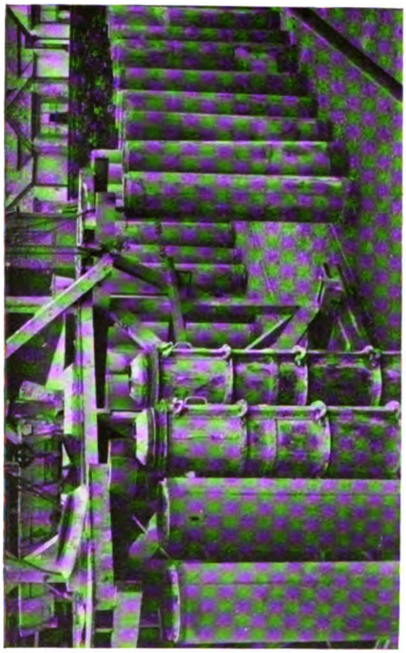


FIG. 9. PIPE CASTING.

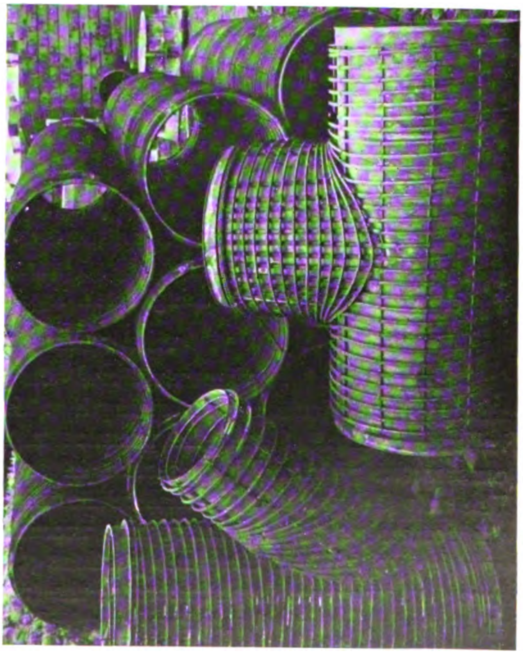


FIG. 7. THE REINFORCEMENT OF SPECIALS.

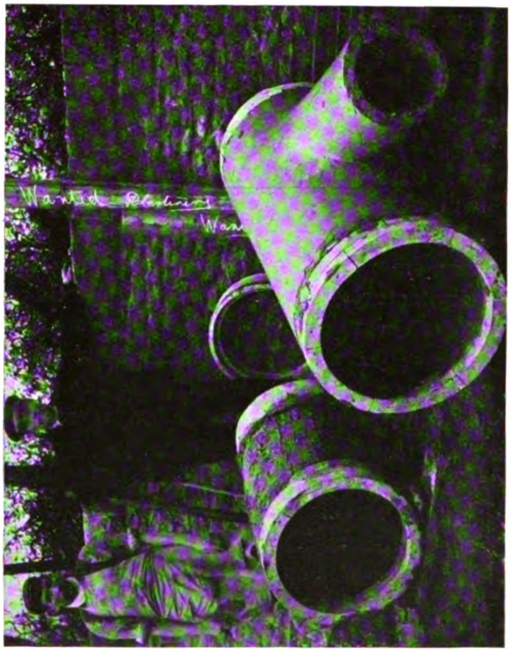


FIG. 8. THE HAND MOULDING OF SPECIALS.

working head on the main is 185 ft.; the length of the main is 1,200 yards; and the internal diameter was intended to be 18 in., but as moulds for this size were not immediately available, moulds for a pipe half a metre or 19·7 in. diameter were accepted instead, on the application of the contractors for the work, the Columbian Fireproofing Co., Ltd., of London, who are executing the work under the patents of Mr. Aimee Bonna, of Paris, of which they are the owners.

As will be seen from the section of the pipe joint (*Fig.* 1), the pipe consists of an interior tube or sheet of mild steel, one millimetre thick, built up in sheets manufactured locally; the longitudinal joints of this tube are made by a welded butt joint; this welding is done in the contractors' yard adjoining the route of the main. At first sight it may seem that this joint is not to be relied upon for strength, but the writer has made many experiments upon test strips cut from the pipes, with the following results:—

Strength of steel in tube, 21·35 tons per square inch.

Strength of butt-welded joint, 21·5 tons per square inch.

The strength of the joint is thus slightly stronger than the original steel sheet; the welding is done by a blow pipe using acetylene and oxygen (*Fig.* 2), which is found to be more convenient than the oxy-hydrogen flame originally used and the joint is slightly stronger, the strength of the oxy-hydrogen joint being 20·06 tons per square inch. The circumferential joints in the tube are made by turning up the edges of the sheets and welding the adjoining edges (the machines used for this purpose are shown in *Fig.* 3); this gives a flexible or expansion joint, but the strength is not more than one-third that of a butt joint; this is immaterial, as strength at this joint is not required, only water-tightness; the ends of each tube are turned up and a collar made of sheet steel is turned up to form a stop end for the external cement coating; this collar is welded to the end of the tube and a strong finish is thus obtained, and on the outside of this the bitumen forming the water-tight portion of the joint is run inside a temporary steel ring used for this purpose only, and which is removed when the bitumen is set. The external reinforcement consists of bars of + section wound in helical form around longitudinal parallel bars of smaller cross section, all the crossings of the tube being wired together, as shown in *Fig.* 4.

THE REINFORCEMENT.

The external reinforcement and the steel tube only are taken into consideration in calculating the strength of the pipe, and the distance apart of the helices is varied to suit the pressure in the main. An internal reinforcement constructed with a lighter section of bar is constructed in the same manner. The only duty of this internal reinforcement is to support the inner portion of the cement and is not taken into account in the calculations for the strength of the pipe. When the three portions of the steel skeleton are completed, the inner reinforcement is placed inside the tube and the outer reinforcement outside the tube; they are then placed vertically on curved wooden curbs made to the exact shape necessary to centre them and preserve the correct thickness of the cement coating.

MOULDING.

A collapsible core is then lowered into position in the inside, and sheet, steel moulds outside, the space between the core and the mould being then run with mortar consisting of two parts of sharp clean river sand to one part of Portland cement, mixed on an elevated travelling platform to the consistency of thin mortar, so that it will flow readily and completely surround every portion of the enclosed steel. During the process of running the cement, the outer steel mould is sharply struck with wooden mallets to facilitate the escape of air bubbles. This part of the construction is clearly shown in *Fig.* 5, from which will be seen the core being withdrawn to be placed in the steel skeleton on the left of the illustration, and a finished pipe is shown on the right. Although this portion of the work appears to be simple, yet very great care has to be exercised, and only experienced men should be employed; as is well known, the time of setting varies with the temperature, the mixture, the quality of the cement, and other conditions. It is therefore necessary to carefully consider each of these points separately, and afterwards together, before it is possible to know with any degree of accuracy when to draw the core and remove the external moulds. The variation in the time of setting occasioned by temperature alone in the same cement is shown in diagram *Fig.* 6, from which it will be seen that in summer 25 minutes are sufficient, but with the temperature at 45 deg. Fahr. five hours will be necessary. With four sets of moulds, a gang of eight men will cast sixteen pipes per day under favourable conditions, but when the temperature is low it may not be possible to make more than four to six pipes. It is therefore necessary to use a cement which can be relied upon to act regularly as regards time of setting so that the moulds can be drawn at the right moment; the cement must be of high quality, and, in the water main under consideration, the cement was specially prepared by the Associated Portland Cement Manufacturers, Ltd., and after the workmen once became accustomed to the speed of setting, they could gauge the correct time for removing the moulds with considerable accuracy. When the moulds are taken off, the pipes are allowed to stand vertically for four or five days to harden, after which the pipes are removed by a crane and laid in stock until required. It is advisable to have a pipe made 28 days in advance of the time it is to be laid, by which time it will stand as much rough usage as a cast-iron pipe.

BENDS AND SPECIALS.

Bends and all junction specials are made with great ease (see *Fig.* 7); a drawing is given to the wiremen who then construct the steel skeletons from it, but in this case the specials are not cast the same as plain pipes, but the steel skeleton is enclosed in its protecting cover of mortar by hand moulding (see *Fig.* 8), the mortar being of stiffer consistency. Specials are made in two days, and the system thus presents advantages over either cast-iron or steel pipes, more especially as the angle of splay or the radius of the bend can be executed by the workmen to suit the actual special requirements of the case, and with practically no greater trouble than is necessary for a stock pattern.

LAYING.

When the pipes are laid in the trench the bitumen joint is first run and is then protected and held up to its work by being enclosed in a collar (see

Fig. 1), formed of the same mixture as the body of the pipe and reinforced by a helical coil, the space between the collar and the pipe being run with cement mortar; after the cement is set the filling in of the trench proceeds. The pipes are made in lengths of 9 ft. 9½ in., and weigh each 12 cwt., about one-third the weight being in reinforcement. The pipes, being of such convenient size and weight, are handled by ordinary tackle, and pipe-laying proceeds as with an ordinary cast-iron water main. The speed of the pipe-laying is practically the same as that necessary for a cast-iron main of the same size; in the present instance about ten pipes per day were laid by one gang of men, one jointer and his assistant making all the bitumen and cement joints as fast as the gang could lay the pipes. It was found necessary to back up all bends by filling in buttresses of concrete behind them to take the outward thrust from the water pressure which amounted in some cases to over two tons.

SOME TESTS AND CONCLUSIONS.

The writer, being engineer for the work, made many experiments during the process of making and laying the main as to strength and water-tightness, and all these proved satisfactory. The main is designed for a working pressure of 185 ft., but ordinary pipes taken at random from stock were tested in a proving press at the waterworks depot and stood a pressure of 450 ft.; at this point the pipe showed no sign of weakness, but great difficulty arose in making a perfect joint between the end of the pipe and the proving press, and after putting a longitudinal compressive stress equal to 26 tons on the pipe, the testing machine was disabled and the tests could not be carried any further. With other appliances the writer hopes to test some of these pipes to destruction at a future date. The first portion of the main is now in work, but before being used, it was tested as laid up to a head of 382 ft., or over twice its ordinary working pressure. No useful result would be obtained by testing much higher; the straight lengths of pipe would stand the pressure but the bends might be blown out should the concrete abutments give at all.

In the opinion of the writer, founded upon the most careful consideration of the manufacture and tests of the main above described, the reinforced concrete water main, when properly designed and manufactured, may with confidence be used for high pressures, and will in the future compete with cast-iron and steel water mains for all sizes larger than 18 in. in diameter, and the greater the diameter, the more prominent its advantages become. For all ordinary working pressures it appears to be well adapted, and the interior will not deteriorate but will remain a good conduit for water, and the discharging capacity of the main will not be reduced by corrosion as in the case of a cast-iron water main. These advantages are so great, that when they are fully realised, the use of reinforced concrete water mains will largely extend, and as regards reliability, the experience of these mains obtained from Paris is extremely valuable, for when cast-iron mains only were in use bursts were frequent, but since reinforced concrete mains have been in use there—now more than ten years—there has not been a single burst

The reinforced concrete water main above described has been constructed under contract by the Columbian Fireproofing Co., Ltd. of London, who carried out the work with great care and are making a speciality of reinforced concrete pipes.

The Theory of Reinforced Concrete.

By CAPTAIN SEWELL.
Corps of Engineers, United States Army.

The theory of Reinforced Concrete is still a subject of considerable discussion, although the splendid research work done in the United States and on the Continent appears to be bringing matters to a rapid termination. Captain Sewell, of the U.S.A. Military Engineers, has prepared for us the following summary of the present situation as seen from across the Atlantic, and adds his own authoritative views, which have the greater weight from the fact that very considerable works in reinforced concrete are being carried out from his specifications and under his personal supervision.—ED.

It is only within the last few years that the theory of reinforced concrete construction has received serious attention in the United States, from those competent to correctly develop it. Probably one of the earliest trained investigators among American engineers was Edwin Thacher, M.Am.Soc.C.E., who has done much for the theory of reinforced concrete arches ; Fr. von Emperger also did a good deal along the same line in the United States. The serious study of beams, girders and columns is of a much more recent date ; numerous formulas have been devised for beams by many engineers, the writer included, all based on the common theory of flexure, but differing from each other in assumptions of constants, in the forms assumed for the stress strain curve of concrete in compression, and in neglecting or taking account of tensile stresses in the concrete. Much discussion has arisen over these points, and also upon the necessity of mechanical bond, the use of web reinforcement, whether it should be attached to the main bars or not, etc. Columns, so far, have not received much consideration, but they are now receiving the attention they deserve. Many experiments have been made in laboratories and in construction work, especially on reinforced concrete beams. But these tests have been made in entirely independent groups, without any co-ordinate effort or consideration. Naturally, they are not at all comparable. A few tests have been made of columns, but the reinforcement in most of them was not well designed, and the tests have not yet yielded data of much value. Accurately conducted tests of beams have been made, in most cases, by means of a single load, centrally applied; in a few cases, the loads have been applied at two points, generally so spaced as to divide the span into three equal parts. It is manifest that such methods can not develop the full value of web stresses, and consequently, favour the beam in what is perhaps its weakest feature. A good many samples or parts of actual structures have been tested, in practice, with uniformly distributed loads, consisting of pig iron or similar materials. While there is always a certain indeterminate arching action in such a load, whereby the centre of the beam is more or less relieved, these tests have brought out very clearly the necessity for web reinforcement, see for instance *Fig.* 1.

The design of the floor panel shown in the illustration was not as good as it might have been, but it is valuable, as accentuating a certain method of failure often occurring in practice, but less often developed—apparently, at least—in laboratory tests, under centre loads. The writer makes use of the word "apparently," for the reason that he believes that many such laboratory failures were due to the web stresses primarily, and not to the bending moment. Under a centre load the maximum bending stresses and the maximum web stresses occur together, at the centre. Near the supports, the web stresses still have their full value, but the bending stresses are much less. Naturally, even if initial failure occurs under the web stresses, it will be at the centre, rather than the ends. Many such failures at the centre, which have been attributed to the bending stresses, were really initially due, in the writer's judgment, to the web stresses; once actual failure began, both kinds of stress came into play, and somewhat obscured the result; but most of the photographs the writer has seen of such beams, after testing, showed methods of failure much more typical of web stresses than of bending stresses, pure and simple. Where the failure has evidently been by bending alone, the percentage of steel reinforcement has nearly always been very small.

When the failure of a reinforced concrete beam develops a complete system of diagonal cracks—whether near the centre or near the ends—similar to those seen near the ends in *Fig.* 1, it would seem that web stresses have had more to do with it than bending stresses. Cracks due to bending alone should be nearly vertical; final failure should result from the rupture or excessive elongation of the steel, and a square break in the concrete, or else from the crushing of the concrete into small fragments on the upper side of the beam, at the locus of maximum bending moment. A typical failure of the latter kind is almost never seen, because, if there is enough steel to produce it, failure will occur under the web stresses before the bending stresses are sufficiently high. A typical case of failure under bending alone, is illustrated in *Fig.* 2. In this test, a patented bar, with attached diagonal web members, was used. The percentage of steel was quite high, and, but for the web members, failure would, almost certainly have occurred under the web stresses, with a much lighter load.

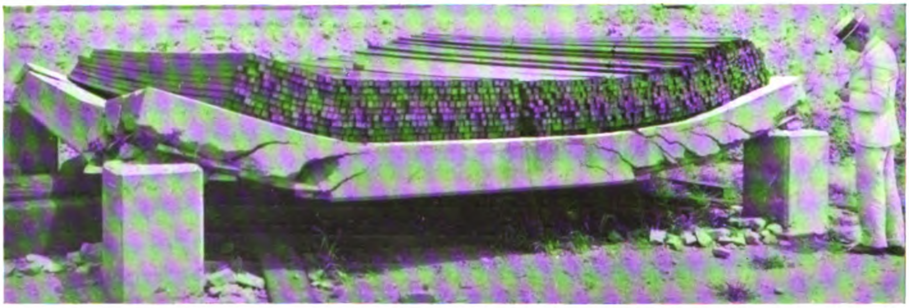


FIG. 1. A TEST TO DESTRUCTION.

No accurately and scientifically conducted tests of beams with complete web reinforcement, attached to the horizontal reinforcement, have ever been made, either in the United States, or elsewhere, so far as the writer is aware. But many tests made in a more or less rough and ready way, have indicated very clearly the value of the attached web members. In one university laboratory, some tests were made on beams reinforced with Kahn bars; but the design was such that the web members did not reach above the neutral axis of the beam. Naturally, their value was not at all demonstrated; if they have any function to perform, it is surely that of transmitting the stress from the main horizontal reinforcement into the compressed part of the concrete; they cannot do this at all unless they reach above the neutral axis—and they cannot do it completely, unless they reach to the very top of the beam.

Although the many laboratory tests made in the United States have not yielded much of value in reference to web stresses and proper means of providing against them, they have yielded a wealth of information on the equally important point of the design of the section of maximum moment. Although the results are not strictly comparable, nevertheless, they are sufficient to enable a good designer to do this part of his work.

A series of tests and investigations is now about to be inaugurated, however, under the auspices of the leading American Civil Engineering Societies, with the co-operation of our National Fire Protection Association, which does much the same useful work as the Fire Prevention Committee of Great Britain. A money grant from the United States Government towards this investigation is anticipated. This series of tests is intended to be exhaustive and authoritative, and, no doubt, when finished, will furnish an adequate basis for a complete theory of reinforced concrete, including its value as a type of fire resisting construction.

In the meantime, engineers and others are losing no time in applying such knowledge as is available. So far as theoretical treatment goes, nearly all American engineers have based their formulas on the common theory of flexure. Probably as convenient a set of formulas as any were those published by A. L. Johnson, M.Am.Soc.C.E., in the catalogues of the St. Louis Expanded Metal Co., of which company he is the engineer. His notation, and the form of his equations, are very convenient, but he takes account of the tensile resistance of the concrete; most engineers in the United States neglect this.

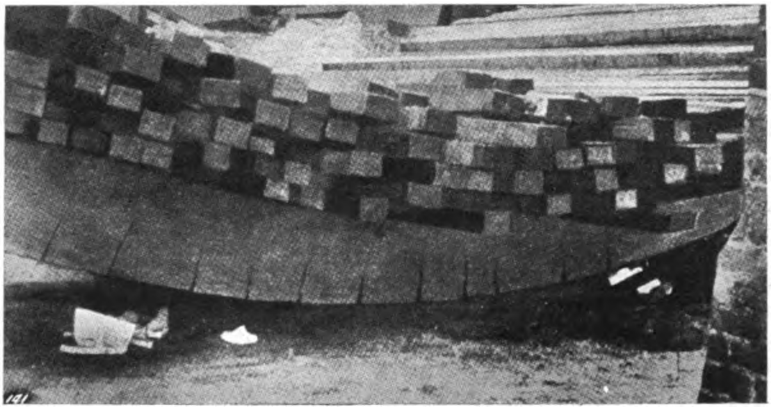


FIG. 2. A TEST TO DESTRUCTION.

Even the simplest formulas, into which the elastic properties of the materials enter, are rather complicated, however; and the tendency now is to use a formula for the design of the section of maximum bending moment, in which the resisting moment of the beam is placed equal to the product of the stress in the steel by a lever arm equal to a constant percentage of the depth of the steel below the top of the beam. The sectional area of the steel is expressed as a percentage of that of the concrete, so as to prevent the use of too much reinforcement. Thus, if b is the width of the beam, and d the depth from the top to the axis of the steel, and a the area of steel reinforcement, $a = pbd$ - - (1), in which p is a constant, varying, generally, from ·0075 to ·0175, depending on the qualities of the steel and the concrete.

If M represent the resisting moment of the beam, t_s the unit stress in the steel, and h, a constant (generally assumed at from ·85 to ·9), $M = hat_sd = ht_spbd^2$ - - (2).

A formula such as (2) is manifestly analogous to those used in designing plate girders, rather than those used for rolled beams. It is much simpler to apply, and if its constants are properly determined, it is just as accurate as any other.

The theoretical treatment of web stresses in the United States is still in a very unsettled condition. There are many engineers who think they can be ignored; many more, who think they can be properly cared for by the use of vertical stirrups, either free or loosely attached to the horizontal bars; a smaller, but increasing number, who think that they should be rigidly attached to the main bars, and inclined at an angle of 45 deg. Those who use unattached web members have various ways of determining their number and spacing; a common way is to assume a certain moderate shearing stress in the concrete as safe, and then to provide for any additional shear by means of vertical stirrups calculated to resist a tensile stress equal to the shear. Such members are sometimes used to resist the horizontal shearing stresses also, in which case their resistance to shearing stresses proper is the basis on which their section is determined.

The writer has never been able to understand the reasoning involved in the method above described for reinforcing against vertical shear. The stirrups traverse the planes along which the concrete would open if failure occurred under web stresses, and, to that extent, they are useful, but that the method employed in designing and spacing them is correct, seems open to some question.

Some experiments made by a very able American engineer to test the value of loosely attached vertical stirrups are worthy of description; plain round bars were used for longitudinal reinforcement; stirrups of round bars, with a rather close turn around the main bars, were used, extending vertically upwards. Instead of concrete, the beams were built up of bricks laid dry, so as to closely envelop the stirrups: when the centering was removed, a certain deflection was at once developed, and the beams then proved to have considerable strength. From these experiments, the conclusion was deduced that loosely attached vertical stirrups were quite sufficient. To the writer, the correct conclusion seems to be that after all the "slack" in the loosely assembled beam had been taken up, friction proved more or less effective as a means of connecting the various elements. If a reinforced concrete beam had deflected enough to take up all possible lost motion between the stirrups and the main bars, it would have been so badly cracked that it would have had to be renewed, in any actual structure. There is no doubt that great carrying capacity can be developed by the use of simple plain bars, without web members of any kind; more can be developed if loosely attached vertical or inclined web members are added—and still more if inclined and attached web members are used, in such a way that they can take their full stress without the possibility of any lost motion whatsoever.

There is a very satisfactory discussion of the web stresses as they actually exist in a reinforced concrete beam in Twelvetree's work, to which reference has been made above; but the author, in suggesting means of resisting them, stops short of what seems the complete solution. Actual tests have shown, however, that the method suggested by him, of using a U-shaped trough of expanded metal around the main rods, and extending vertically upwards on either side, is of very appreciable value. If the main bars could be attached to the strands of the metal so as to take the stress directly from them, the results would undoubtedly be still better. As long as the main bars must take their stress directly from the concrete, even though it be merely an intermediary between themselves and the tensile web members, failure is almost sure to occur, without much warning, when the stress in the main bars reaches the elastic limit: the only exceptions would be cases in which the percentage of reinforcement is much too low to develop the crushing strength of the concrete.

The writer's method for designing and spacing web members is indicated in *Fig.* 3.

Let C D E F represent a sectional side elevation of a reinforced concrete beam, and A-B, the axis of the steel reinforcement. Conceive the beam divided into panels, in which the panel length is equal to the depth of the line A–B below the top of the beam. Draw in two imaginary sets of web members, at angles of 45 deg., as indicated. The web members of one set are shown in heavy lines, and of the other set in light lines, for greater clearness. Compressive members are shown in broken lines, and tensile members in full lines. Conceive the two sets of web members to be entirely independent of each other ; the beam is supposed to be uniformly loaded, but with the loads concentrated at panel points, as shown. The stresses in the tensile web members are determined, and within the half panel length on either side of each tensile member indicated in the drawing, enough actual web members are spaced to carry the stress. They are attached to the main bars, and their section so determined that the adhesion of the web member in the upper compressed part of the concrete shall be sufficient to develop its strength. It will be noted, however, that the tensile web members transmit only one-half of the total stress into the main bars. The other half is transmitted by the compressive web members, which, in this case, consist of the solid concrete of the beam. It is necessary, therefore, in addition to the tensile web members, to provide some form of mechanical bond, properly distributed, to ensure the ability of the main bars to take up the horizontal components of the compressive web stresses. Adhesion alone, in this case, should not be relied upon. It is well enough for the upper ends of the tensile web members, since it will there be increased with increasing loads. But even then, the writer prefers mechanical bond, also, if it is practicable to obtain it. One way of insuring the transmission of the horizontal components of the compressive web stresses, is to use twice as many tensile web members as would otherwise be required ; if the connection of the tensile web members to the main bars could be so devised as to afford the concrete an adequate bond, and so as to be twice as strong as the web members themselves, no special provision for transmitting the horizontal components of the web stresses into the main bars would be needed ; but this is not an easy thing to do. In the War College work, shown in the writer's article in No. 2 issue, twice the theoretical number of web members were used. Some of them near the centre, were inclined towards the farther support, so as to act as counter-braces, under concentrated or non-symmetrical loading.

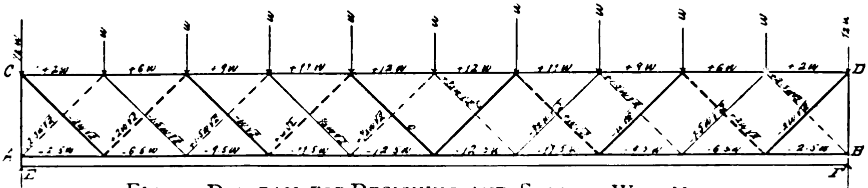


FIG. 3. DIAGRAM FOR DESIGNING AND SPACING WEB MEMBERS.

As reinforced concrete becomes monolithic, the floor systems will act as continuous girders, whether that is desired or not. The tendency in the United States is now towards the use of reverse reinforcement over the supports, making some deduction in the bending moment at the centre of the span, because of the partially fixed ends. So far as the columns are concerned, no theoretical treatment or formula is yet generally accepted ; in fact, much less attention has been paid to column formulas in the United States than to beam formulas, although neither has been neglected. It is probable that the column formula finally accepted and generally used, will be very similar to the straight line formula so popular with designers of steel structures at the present time. It is probable, however, that extensive tables for both columns and beams will be computed, as soon as formulas and methods are generally accepted, so that, in actual design, very few such computations will really be made—suitable sections being selected from the tables

While not perhaps entirely pertinent under the head of theory, it may not be amiss to state here that the tendency in the United States is to provide some form of mechanical bond for all imbedded steel members, so as not to depend upon adhesion alone ; and, if work must be executed in frosty weather, to take adequate precautions to prevent the concrete from freezing.

What has been said above of the theoretical treatment of the subject, describes prevailing tendencies rather than current usage. The New York building law is fairly typical of the latter. It provides that beams shall be designed in accordance with the ordinary theory of flexure, and the assumption that the stress strain curve of concrete in compression is a right line. Certain moderate unit stresses are allowed, and it is provided that where the concrete is not sufficient to carry the shear, steel reinforcement shall be provided, but it does not specify how it shall be used. It is also required that if the adhesion is not sufficient to transmit the stress from the steel to the concrete, other means shall be provided, but what they shall be, or how devised, is not indicated.

It may be difficult to prove that the stress strain curve of concrete in compression is any special curve ; but it is not at all difficult to prove that it is not a right line, nor any very close approximation thereto—at least not with any mixtures likely to be used in the United States. Under the requirements of the New York law, with the assumption of a right line for the stress strain curve, slabs and rectangular beams of considerable span and loadings, while more than strong enough, are very deep, heavy, and expensive, with a proportion of steel much less than economy could warrant. Shallower and lighter beams, with a greater proportion of steel, would cost less, and carry even more load, but they would not comply with the law. But the law permits the use of thin floor slabs and ribs, and allows the floor slab, to the extent of ten times the width of the rib, to be counted as the flange of a tee beam, the rib being its stem. How the compressive stresses that are credited to the flange will be transmitted through the rib to the steel, without longitudinal shearing, is not at all indicated. The deep and heavy slabs or rectangular beams called for by the law, would possess an unnecessarily large factor of safety ; the ribbed constructions permitted as an alternative, would be equally in error in the other direction.

When a formula such as that given in eq. (2) in this paper, is used, it is easy to prove that, if d be the depth of the steel below the top of the beam, and b the width of a rectangular beam, or of the stem of a tee beam, minimum cost in money will result when the total sectional area of horizontal reinforcement, divided by b d, is equal to the cost per cubic foot of the concrete in the section b d, divided by the cost of steel per cubic foot. This applies, whether the beam is reinforced at both the top and the bottom, or at the bottom only.

The formulas published by A. L. Johnson, to which reference has been made above, afford a rational means of determining the proper width of flange for each width of stem, in tee-beams. The flange, by these formulas, generally comes out not more than four times as wide as the stem, and the writer never uses a width of floor slab greater than three times the width of the rib.

The only reason for computing a ribbed floor system as a series of tee-beams is the fact that the economical proportion of reinforcement, determined on the basis of cost alone, is often too great for the strength of the concrete contained in the section b d. Including a reasonable width of floor slab as part of the compressive section of the beam will usually justify the use of the full economical proportion of steel, in such cases.

Recent Examples of Steel and Concrete Buildings in Scotland.

By J. ROXBURGH SHARMAN, A.M.Inst.C.E.

The unfortunate manner in which the advantages of steel skeleton construction are discounted by out-of-date regulations is obviously detrimental to sound and economical building in our isles. As in the case of an article presented in our first issue, the author here refers to the difficulties that have to be contended with. But at the same time he describes and illustrates two excellent examples of Scotch constructional engineering, which do great credit to our friends beyond the border.—ED.

THE use of steel as the important factor in the construction of many recent buildings both in London and the provinces, is a clear indication that this method of construction is rapidly increasing in this country, and there are likely to be large developments in this direction in the near future. In spite of the London Building Act of 1894 and the Municipal Regulations in most of the provincial towns, which ignore this style of construction, its advantages are becoming apparent to most architects who keep abreast of the times; and, without adopting complete American methods, there is much that can be learned from the bold and original designs of the high buildings in America, which can be usefully applied to the different style of building required in this country. Without advocating the adoption of buildings of twenty-five or thirty stories high in our cities, there is no doubt that a modified form of the steel frame construction possesses many advantages for the ordinary high building of seven or eight stories with which we are familiar. It is the object of this article to describe certain recent buildings in Scotland as illustrating the stage which has been reached, and the direction in which further developments in this method of construction may be expected, also to consider what safeguard must be taken to ensure that any such developments are on correct lines, tending to economy and stability. It is also the object of this article to examine in some detail the advantages which a complete steel frame building undoubtedly possesses for many purposes over the ordinary building in which the walls are entirely of brick or stone.

The following illustrations of two well-known recent buildings in Scotland, Messrs. Singer's factory at Kilbowie, near Glasgow, and the new *Scotsman* office building in Edinburgh, show the advantages of steel columns in the interior of large buildings of two distinct classes. The first is one of the largest factories in the world, and the second one of the largest and best equipped newspaper offices. The latter is, in addition, one of the architectural features in the picturesque capital of Scotland. The succeeding illustrations of two office buildings in Glasgow represent more nearly the steel frame structure as used in America, and illustrate the additional advantages of steel columns built into the walls.

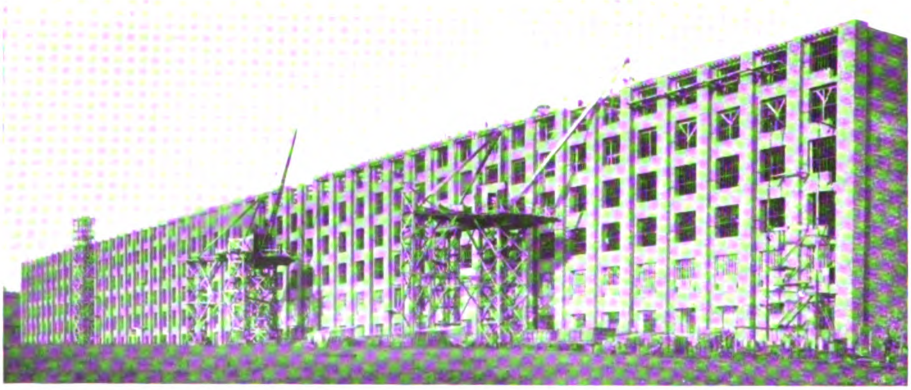


FIG. 1. NEW CABINET FACTORY OF THE SINGER MANUFACTURING COMPANY.

New Cabinet Factory at Kilbowie.

Fig. 1 represents a general view of the New Cabinet Factory at Kilbowie, of the Singer Manufacturing Company, erected by Messrs. Robert McAlpine and Sons from designs by Mr. Robert Whyte, architect. It constitutes a record in building construction, so far as concerns the dimensions of the structure, the rapidity of erection, and the extent to which ferrolithic has been used. The building is 800 ft. long and 80 ft. wide, with six floors, making a height from ground level of 90 ft., the total contents being about 6,000,000 cubic feet. The walls are 36 in. thick at the base, reduced to 18 in. at the upper floors, with butts 4 ft. wide, projecting 18 in. from the face, spaced at 15 ft. 4 in. centres (see *Fig.* 2).

Plan and Elevation of New Factory.

The floors are carried by three rows of steel columns running the length of the building, spaced about 20 ft. apart. In the other direction the columns are 15 ft. 4 in. apart, in line with the butts in the walls. The main cross-girders are firmly riveted to the columns and rest on the walls at the two outer ends, carrying the longitudinal

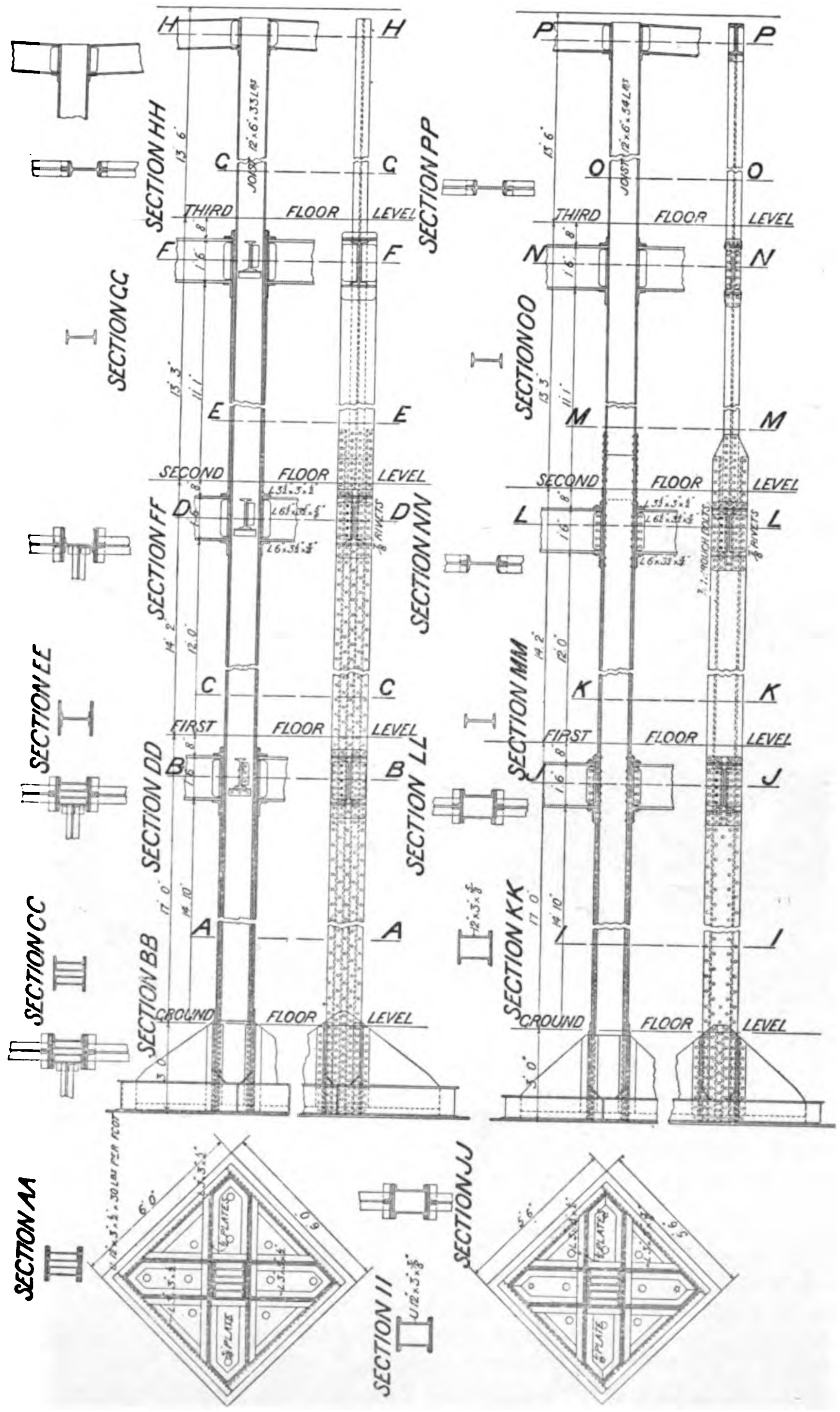


FIG. 2.—NEW CABINET FACTORY OF THE SINGER MANUFACTURING COMPANY.
Details of Steel Frame Construction.

or floor girders which run over the top of the former, and are spaced at 3 ft. 3 in. centres this construction being clearly shown in *Fig.* 3.

"Ferrolithic," or slag concrete, was laid between the joists to a minimum depth of 4 in. Over this, wooden joists were laid diagonally at 18 in. intervals, these being 2 in. thick, and again "ferrolithic" was worked flush with the diagonal timbers, increasing the thickness to 6 in. Two layers of timber flooring were next put down, the top layer being transverse to the lower. There is thus a minimum thickness of 8 in. in the floor, and it is designed to carry a load of 300 lb. per square foot.

The "ferrolithic" with which the steelwork was encased (as shown in *Fig.* 4) constitutes one of the interesting features of the work. It is composed of the slag from Siemens-Martin steel furnaces broken to cubes of 1½ in. diameter, the remaining powder being used instead of sand. The proportions are four parts of large material to one part small, and one of Portland cement. The concrete thus formed is said to have a considerably higher tensile strength than concrete made in the same proportions with crushed granite; it is an exceedingly good fire-resisting material, and can be finished to a very fine surface. The joists, main girders, and columns are encased throughout with this material to a minimum thickness of 1½ in.

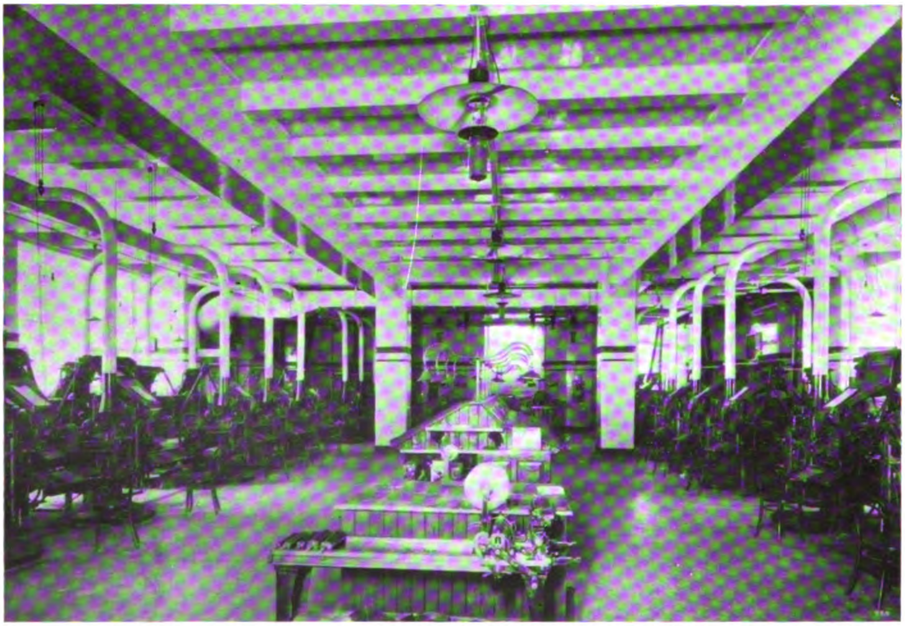


FIG. 5. NEW *Scotsman* OFFICE BUILDING. VIEW OF THE LINOTYPE ROOM, SHOWING COLUMNS ENCASED IN BRICKWORK AND CONCRETE COVERING TO FLOOR BEAMS.

The steel columns in this building are made up on the lower floors of 12 in. by 3 in. channels, with side plates 14 in. wide, the size of channels and the number of plates varying with the loads, and on the top floor the columns are reduced to 12 in. by 6 in. joist section. Each length is two floors in height, and it should be noted that the joints in the columns are above floor level, and are butt-joints covered with vertical splice plates. This is a great advance over the horizontal top and bottom plates, which are often used in this country for steel column joints, a survival from the older practice commonly employed with cast-iron columns. The advantages of the former methods are obvious, as they allow of close contact between the section of adjacent lengths, also, the joint being above, and clear of, the connection to floor girders, the latter can be erected at the same time as the columns. The connection does not interfere with the erection of the next length of the columns, and there is no necessity for temporary guys.

This building is a very instructive example of a modern factory, and the symmetrical nature of the design as regards walls and steelwork was, no doubt, intentional, in view of the rapid erection required. The quantities of materials in this building are as follows:—Bricks, 23,000 tons; concrete in foundations, 7,000 tons; concrete in ferro-lithic, 14,000 tons; steelwork, 4,000 tons; timber, 1,500 tons. The fact that it was completed in the extraordinarily short time of six months, shows that with proper organisation and care we can, in this country, erect work as expeditiously as it can be done elsewhere.

The "Scotsman" Building, Edinburgh.

The next illustration (*See* p. 199) shows the *Scotsman* Office building recently erected in Edinburgh. This view is taken from the North Bridge over the Waverley Station, and only shows the portion of the building above this level.

This fine building was designed and carried out by Messrs. Dunn and Findlay, architects, Edinburgh, and the author is indebted to Mr. James B. Dunn, F.R.I.B.A., for the particulars given here. The outer walls are of cube stone rubble, treated in a very artistic way, and the internal partitions of brick. The floors are composed of steel joists at approximately 5 ft. centres, with concrete filling about 6 in. thick. On the upper floors, the concrete is composed of one part cement to four parts of coke breeze, laid 4 in. thick. After pipes, etc., were in position, an additional 2 in. was added, composed of one part cement to two parts of coke breeze. The concrete for the lower floors was made of one part cement to four of granite, crushed to pass ½ in. mesh, and an additional 2 in. added of one part cement to two parts of granite chips.

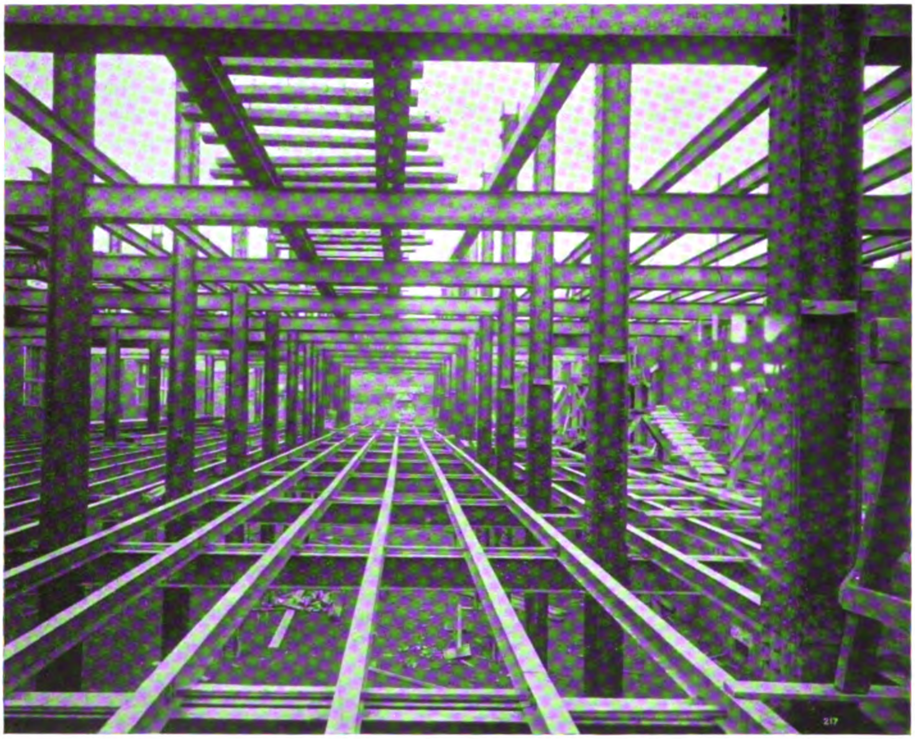
The beams are all encased in concrete, one part cement to four of granite chips, and are covered to a minimum of 2 in. thick, iron wire, ⅛ in. diameter, being first wound round the beams to act as a support to the covering. The columns, throughout this building are encased in brickwork set in cement. *Fig.* 5, a view of the linotype room, shows the internal appearance of the columns and ceilings.

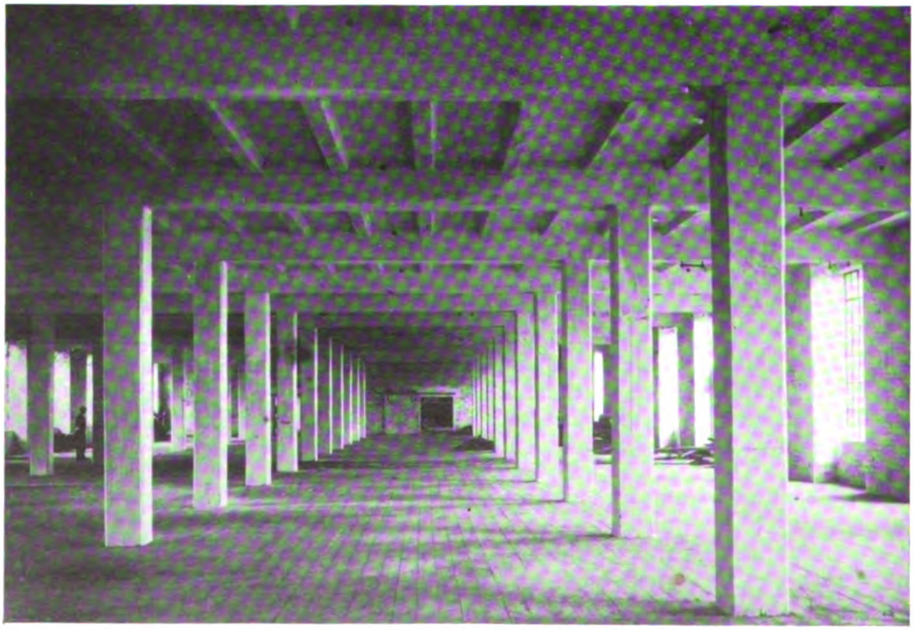
The steel columns are built up sections, composed of joists, channels and plates of varying scantlings, to suit the different loads they have to carry, the heaviest loads on some of the lower lengths being some 700 to 800 tons. All the connections of girders to columns were riveted wherever practicable, which tends to give greater stiffness to the whole of the structure than is possible with bolted connections.

The cost of the steel contract for this building amounted to approximately £24,000, and the total contract price was about £300,000, exclusive of the site, which cost some £120,000 additional.

Typical Examples.

The two buildings described above are good illustrations of the best modern practice with regard to the use of steel columns in the interior of such structures. The direction in which we may look for further developments in steel construction lies in the extended use of steel in the form of columns or standards, built into the walls and taking the principal part of the weight of the floors and walls above. In most large buildings in our towns, such as hotels and offices, the largest rooms are required





FIGS. 3 AND 4. THE SINGER FACTORY. INSIDE VIEWS BEFORE AND AFTER COMPLETION.

on the ground or first floors, and also the largest window area, as the light is often cut off on these floors by adjacent buildings. Such large rooms entail heavy girders, transmitting the weight of upper floors and partitions to the walls, and the piers between the windows must be so large that it is often impossible to obtain the required window area.

With steel standards built into the walls and carrying the girders it is possible to reduce the piers so much that the maximum window area and ample stability can be secured at the same time. Built steel standards, composed of ordinary rolled sections riveted together, are eminently suited for such columns; they are easily obtained and quickly made, any flaw or defect is obvious and on the surface, not hidden as it may be in the case of a cast-iron column, and the strength of such standards is accurately known by calculation checked by numerous tests.

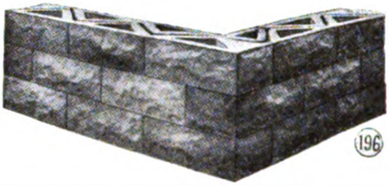
Safeguards in Design.

The safeguards required to ensure stability and economy in steel frame construction are, in the first place, skilled design and careful supervision of the work. The design of such work is a subject that requires special training and experience. In America consulting engineers are employed who make a speciality of this work. They are instructed either direct by the principal or through the architect, and are responsible for everything connected with the steelwork. In this country the same method is now often adopted, with advantage to all concerned; it saves the architect from a great deal of detail work, which he often has not men fully qualified to undertake, and the difference in cost between a steel structure designed by an engineer with the necessary theoretical and practical knowledge, and the same work designed by a man without the special training necessary will often pay the engineer's fee many times over, besides being a guarantee that the work is correctly proportional to the loads.

Safeguards against Fire and Corrosion.

The next important matter is to see that the steelwork is protected in the most efficient manner from the action of fire and damp. Probably the best possible protection against fire is a covering of good brickwork composed of hard, well-burnt bricks, set in cement. In the case of steel columns occupying a position in the walls of a building they should be completely built around in this manner, and in the case of columns in the interior of a building the same method of protection may be employed with advantage, as described above, in the case of the *Scotsman* Office. The most instructive object-lesson the world has ever had in this matter was the large conflagration some years ago in Baltimore. The area which was gutted by this fire was covered with buildings of every description, including many so-called "fireproof," which suffered more severely than other older buildings not so designated. The recent terrible disaster in San Francisco will, no doubt, also furnish much valuable information in due time, which may prove of service to mankind in helping to minimise the effects of fire under similar circumstances elsewhere. From Mr. Edwin O. Sach's report to the British Fire Prevention Committee on the Baltimore fire, we gather that the best protection for steel is brickwork, as described above, or a covering of concrete made with a good fire-resisting aggregate, such as clinker, pure slag, or well-burnt broken brick, all steelwork to be encased with such covering to a depth nowhere less than 2 in. thick.

Types of Hollow Concrete Blocks used in the States and their Patents.



By W. M. TORRANCE.

The increasing popularity of hollow concrete blocks for domestic buildings in the United States calls for serious attention in the British Isles, and more particularly in those districts where the primary constituents of the hollow block, namely, Portland cement and sand, are obtainable at a moderate figure. The paper presented in our No. 2 issue should serve as an excellent argument in favour of the adoption of such blocks in building practice. The Cheap Cottages Exhibition of last year clearly demonstrated that there was nothing to fear on the artistic side from hollow concrete blocks. The practical advantages are obvious.

In introducing a new development of building construction in Great Britain, it would be well if designers and manufacturers were to carefully consider the question of patent rights. The position of affairs can, of course, be easily and inexpensively ascertained as far as British patents are concerned, but the home of the hollow block industry is the United States, and for this reason some summary of the types of hollow concrete blocks and the patents taken out in the United States should facilitate inquiry into the subject. For this reason we present a section from a most valuable article prepared for the "Cement Age," in the course of a competition for a treatise on the manufacture of concrete blocks and their uses. We are also indebted to the "Cement Age" for the illustrations shown.—ED.

WHEN concrete first came into general use, it was probably used mostly in making large blocks, at convenient places, to be used, after becoming thoroughly set, in building large sea walls and other heavy masonry structures. The idea of moulding a monolithic wall was a later development. The idea of making a wall hollow for the sake of economy, or for prevention of moisture or frost working through was a still later development. At the present time, practically all concrete block manufacture is designed for making a wall with hollow blocks, with continuous air chambers in the wall, or by making blocks which, though not perhaps themselves hollow, will lay up into a hollow wall.

The steps leading up to the present state of the industry were all patented by their inventors, and the man who desires to go into a concrete building block business will do well to look thoroughly into the patent rights question.

In 1850, Joseph Gibbs was granted the British Patent No. 13,071 on several improvements in the manufacture of cement and concrete. His patent included the method, now so common, of building solid concrete walls by means of timber forms or lattices on either side. The specification continues :—

> When it is thought advisable to dispense with the lattices, and to make the wall without any part of it being composed of wood, then in such cases, blocks of the size of the stone of which the wall would be composed under ordinary circumstances are to be cast, only these blocks are to be hollow, having only sides and ends, the sides and ends being only about 2 in. thick. After every course of these blocks has been built, the hollows must be filled with concrete like that before described. The blocks being made to break joints with each other, and being filled with cementitious matter, the wall will become one mass of solid artificial stone, so there will be no necessity to put mortar between the blocks to bed them. Instead of the blocks being cast in the shape of hollow parallelograms they may have merely a back and a face,

> such back and face being held together by only as much cement or other material as will keep such back and face in parallelism with each other during the time they are setting (after which the filling must be the same as before). It will be well to wet the blocks before concreting cement is put in, so that they may all unite to form a solid mass of artificial stone.
>
> Having described the second part of my invention, I declare that what I claim in respect thereof is as follows : . . . .(3rd) I claim the process of moulding artificial stone by putting plastic materials between lattices or other convenient forms, and also the method of casting hollow parallelograms in cement to be afterwards filled up with concrete for artificial stone.

It is evident from this description that the inventor did not intend to use his invention for hollow walls, but it is certain that many walls were built in England and Scotland by both the systems above described in which the builders did not complete the process, but left the wall hollow ; and it seems possible that the granting of this patent (which long ago expired) may be construed as invalidating many more recent patents on hollow blocks and hollow walls.

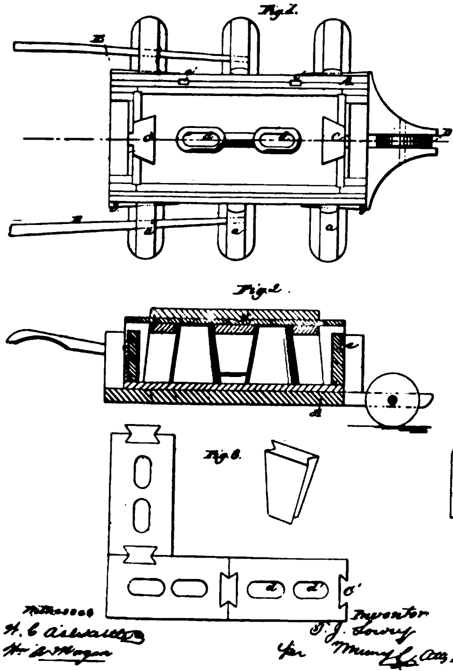


FIG. A. LOWRY'S PATENT MOULD FOR BUILDING BLOCKS, 1868.

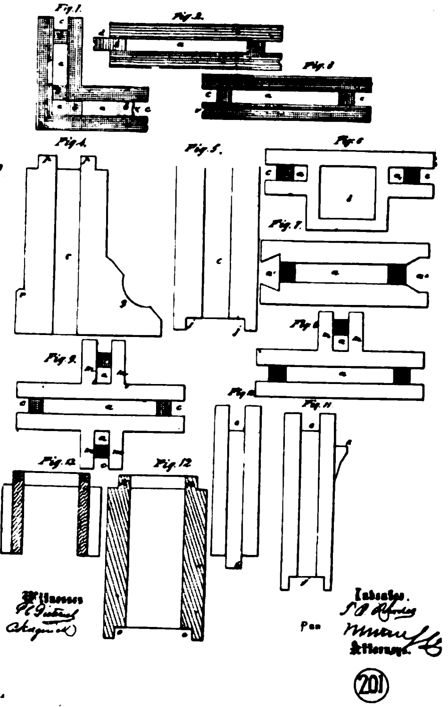


FIG. B. RHODES' BUILDING BLOCK PATENT, 1874.

In 1868,* Thos. J. Lowry was granted U.S. Patent No. 80,358 on a hollow block and wall, the block being almost the exact shape of those made by use of many of the hollow block machines or processes now in use (see *Fig.* A).

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* Since this article was submitted in this competition the writer has discovered a still earlier patent, viz. : No. 53,004, granted March 6, 1866, to C. S. Hutchinson, on a hollow building block and wall, making continuous vertical air spaces. This block is remarkably similar in many respects to the hollow building blocks on the market to-day.

In 1874, T. B. Rhodes was granted U.S. Patent No. 149,678 on a great variety of forms of hollow building blocks and hollow shingles, of "concrete or other material, which in its plastic condition may be moulded into the required form." *Fig.* B is from one of the three sheets of drawings which accompanied the patent. In this patent, no method of moulding the blocks is shown or suggested, so that a broad interpretation of the patent would be that it granted Mr. Rhodes the exclusive right to make blocks of these forms by any method of moulding then known.

The H. S. Palmer Co., of Washington, D. C., appear to claim in their literature the right to control by virtue of their patents the basic principle of hollow concrete building block machines with removable cores and adjustable sides. Their patents also cover certain forms of block. *Fig.* C shows the drawings accompanying Patent No. 674,874. This patent, and others controlled by the same company, if rightfully granted, are evidently being infringed on by the makers and users of a great many other machines. The makers of these other machines and devices are practically unanimous in their claims that the Palmer patents, as far as the block or wall is concerned, are void, and appear to act under this belief. Consideration of the patent 80,358 to Mr. T. J. Lowry, of the patent No. 149,678 to T. B. Rhodes, patent No. 53,004 to C. S. Hutchinson, and the British patent of Joseph Gibbs in 1850, naturally lead one to question which is right.

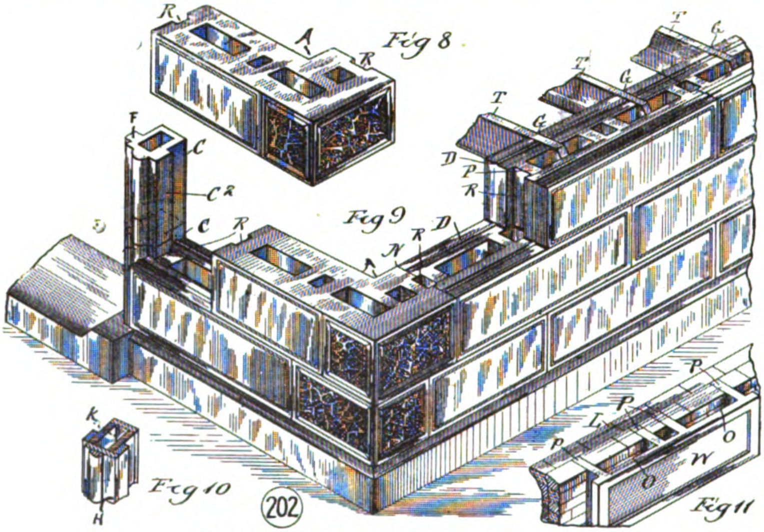


FIG. C. PALMER PATENT OF 1900.

There are at least two types of block made of width equal to the whole thickness of the wall in which there are no webs that pass directly through the wall, viz., the "Miracle" and the "Blakeslee," both of which are patented—*Figs.* D and E, patent drawings. These two types, though accomplishing the same purpose, are different in form. One makes a wall with vertical, the other with horizontal air passages.

The first claim in the "Blakeslee" patent is "A building block wherein there are no continuously solid portions from front to rear." This patent was filed December 19, 1903, and bears the date May 24, 1904, the patent being No. 760,774. The third claim of the "Miracle" patent covers "A building wall consisting of concrete blocks having two rows of air cavities, the cavities of the one row being opposite and being larger than the intervals or necks between the consecutive cavities of the other row, etc. This is patent No. 730,780, filed December 1, 1902, and issued June 9, 1903.

The patent records show that application for a U.S. patent on a multiple air space wall was filed December 4, 1903, by Peter Dierlamm, of Stratford, Canada. This patent, No. 774,835, was granted in November, 1904. The drawing accompanying this patent shows that this patented block is almost exactly the same form as the "Miracle" block. Application for this patent was filed prior to the application for the "Blakeslee" patent No. 760,774.

Fig. D (*Fig.* 3) shows a horizontal section of a portion of a "Miracle" wall. *Fig.* E (*Fig.* 10) shows a vertical section of a portion of a "Blakeslee" wall. The writer has added to *Fig.* 3 three lines marked AA, BB, CC. These lines show how four "Blakeslee" blocks would make one block similar in form to a "Miracle" block turned on end. Practically the same thing would be true of a block of the form patented by Peter Dierlamm.

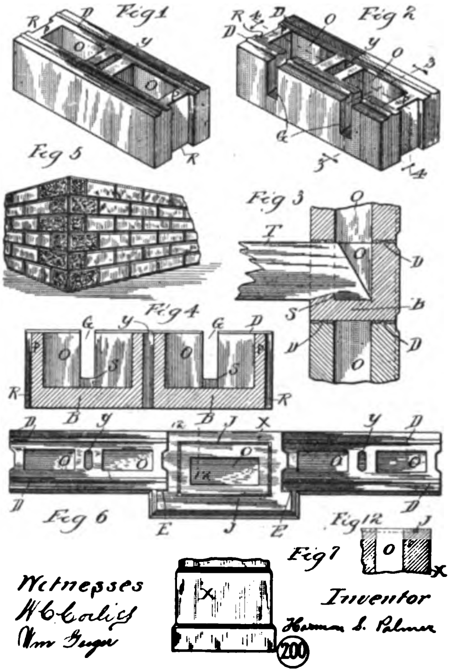


FIG. CA. PALMER PATENT OF 1900.

The "Blakeslee," "Dierlamm," and "Miracle" blocks are improvements on blocks of the "Palmer" type designed to prevent moisture from passing through a wall by doing away with webs passing direct from front to rear. Both the "Blakeslee" and the "Miracle" processes use "dry" concrete, the machines being somewhat similar to those used in the Palmer process, which also uses "dry" concrete. Nearly all the competitors of the Palmer company which make blocks of forms like or similar to the Palmer blocks also use "dry" concrete. The object gained by using "dry" concrete is rapidity of manufacture, as a block may be removed from the machine as soon as it is tamped and the next block may be started at once which could not be done by use of "medium" or "wet" concrete.

Purdy and Henderson, of New York, have recently invented a process which will allow the use of "dry" concrete in blocks made on a machine of the Palmer type and yet make blocks that will not allow the passage of water or frost from front to rear owing to the insertion of a waterproof slip. *Fig.* G shows this improvement, which is described as follows:—

There are on the market at present at least three processes of hollow wall construction which do not use the "dry" concrete, viz., by casting "wet" concrete in metal moulds by mixing "medium" concrete and moulding same under pressure by machinery, and by casting "wet" concrete in sand. In all these processes gravel or broken stone may be freely used.

The process of casting "wet" concrete in metal moulds is comparatively cheap, one of the chief items of expense being the great number of metal moulds required.

These are made with collapsible core pieces and of hinged joints, so that, after setting, the block may be removed.

Fig. H shows Patent No. 704,606, of the American Hydraulic Stone Co., of Denver, on its "two-piece" system of hollow wall construction. This company uses in its machinery "medium" concrete compacted by great pressure in the machine. There are numerous advantages to this system over many others now in use, a few of which are here given.

1. The chance to make the wall, and the individual webs of the wall, any thickness desired, by simple adjustments of machinery.

2. The chance to use ¾ in. or 1 in. gravel or broken stone in the aggregate, thus making a true concrete.

3. The patent rights held by this company seem to be very broad, and, if they will hold, they cover almost any conceivable arrangement of blocks of concrete or other material in which the faces are of separate pieces bonded together in the middle of the wall by T, L, or channel projections extending into the middle of the wall.

4. The method of manufacture adopted by the use of the patented machinery of this company allows the use of sufficient water to make a "medium" mixture of concrete.

5. The continuity of both horizontal and vertical air spaces. One of the most ingenious devices of this system of laying walls is the continuous horizontal air space which extends throughout the wall, making in effect two walls tied by the overlapping of webs in alternate courses; thus a very thorough insulation is secured, making a concrete wall construction impenetrable by moisture.

6. The securing of a very large percentage of air space.

7. The ability on account of the through bond, to construct a wall of any length without providing expansion joints. Long walls of "one-piece" blocks have given trouble where such joints were not provided.

8. The greater ability to use the inside surface of an outside wall built by this process for a surface on which to plaster without furring and lathing. These blocks to be used for inside face of the wall are left rough, without the application of a smooth finish, so that an excellent bond with the plaster is assured, and the wall being in two pieces can be kept in alignment very easily so as to insure a uniform thickness of plastering. *Fig.* K shows how continuous horizontal and vertical air spaces throughout the wall are obtained.

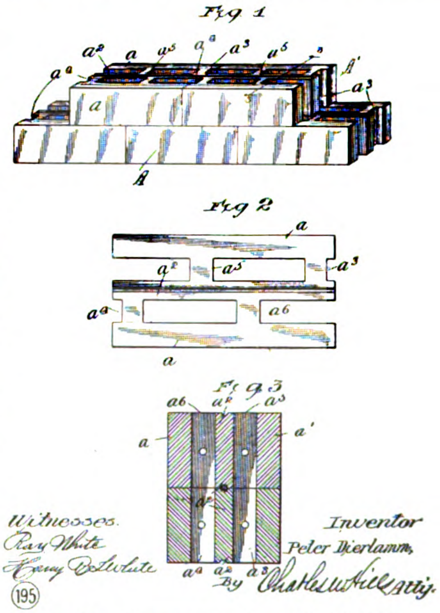


FIG. F. DIERLAMM PATENT OF 1904.

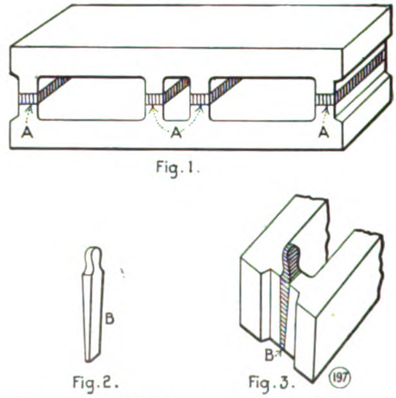


FIG. G. PURDY AND HENDERSON'S PLAN FOR MAKING WATERPROOF BLOCKS.

The process of casting "wet" concrete in sand is very adaptable in buildings where the architecture requires arch stones, plain or fluted columns, ornamental caps and sills to windows or doors, ornamental water tables and cornices, etc.

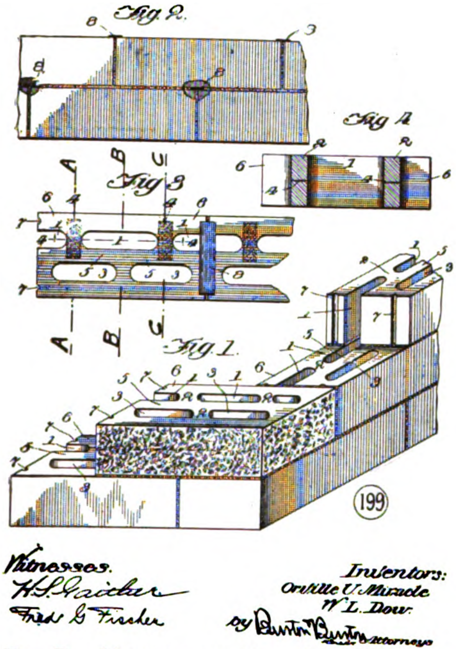


FIG. D. MIRACLE AND DOW PATENT OF 1903.

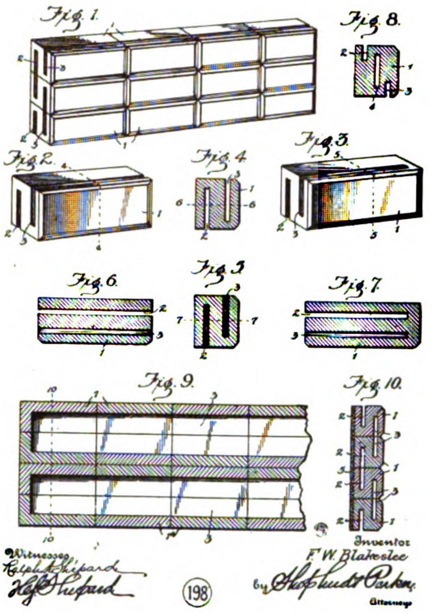


FIG. E. BLAKESLEE PATENT OF 1904.

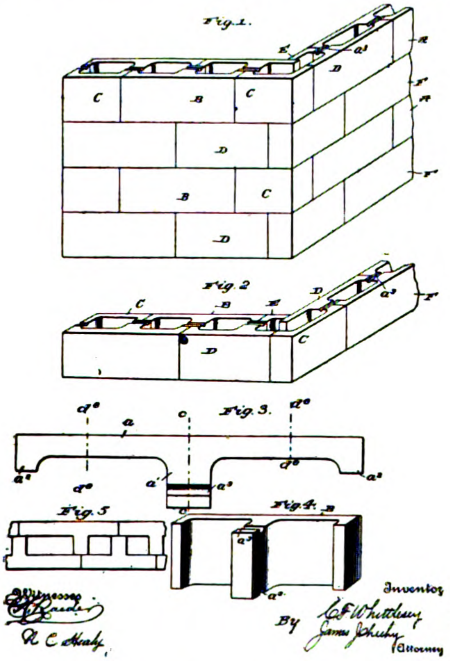


FIG. H. WHITTLESLEY PATENT OF 1902 (AMERICAN HYDRAULIC STONE COMPANY).

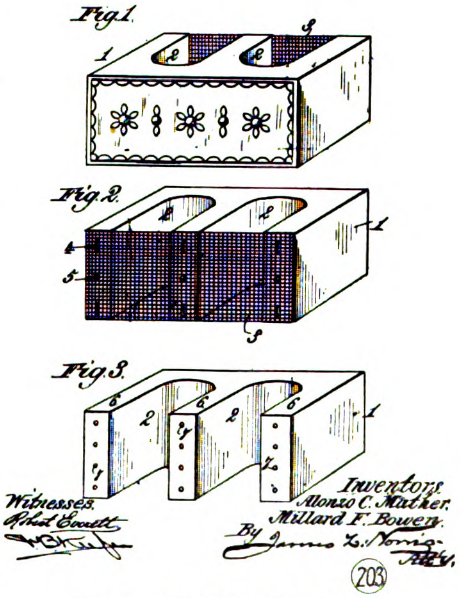


FIG. L. MATHER AND BOWDEN PATENT.

Patents Nos. 583,515, 699,587, 699,588 and 624,563, granted to C. W. Stevens, are held by the Stevens Cast Stone Co., of Chicago, on this process. This company, in applying for a patent in Germany, was told that it was not believed possible to successfully cast concrete in sand, so men were sent to Germany to demonstrate the process. The patent was granted.

These patents cover broadly the process of casting any shape, more particularly hollow shapes, of concrete in sand moulds or moulds partly of sand and partly of other materials.

The literature of the Mandt Cement Block Co., Stoughton, Wis., illustrates a novel multiple air-space wall. This is a two-piece wall, as may be seen by the illustration, at the head of this article. Application for patent on this block and wall was filed May 10, 1905.

Attention is called to Patent No. 776,409 granted to A. C. Mather and M. F. Bowen. Fig. L shows the plan of this block, which, when laid up, becomes a well bonded wall with a hollow back to the channel projections, on each block of which wire lath is attached for plastering. This form of block is one of the forms used by the American Hydraulic Stone Company in its patented "two-piece" wall, and could easily be made of impervious stone broken concrete on the machines of that company. The writer has seen no advertisement of any company using this block.

The literature of the Queen City Brick Machine Co., Traverse City, Michigan, illustrates a process of making ordinary-sized bricks of concrete composed of sand and cement, by pressure, by use of their patented machinery (Patent 761,886). These bricks are all of the same size and may be made with ornamental faces, etc.

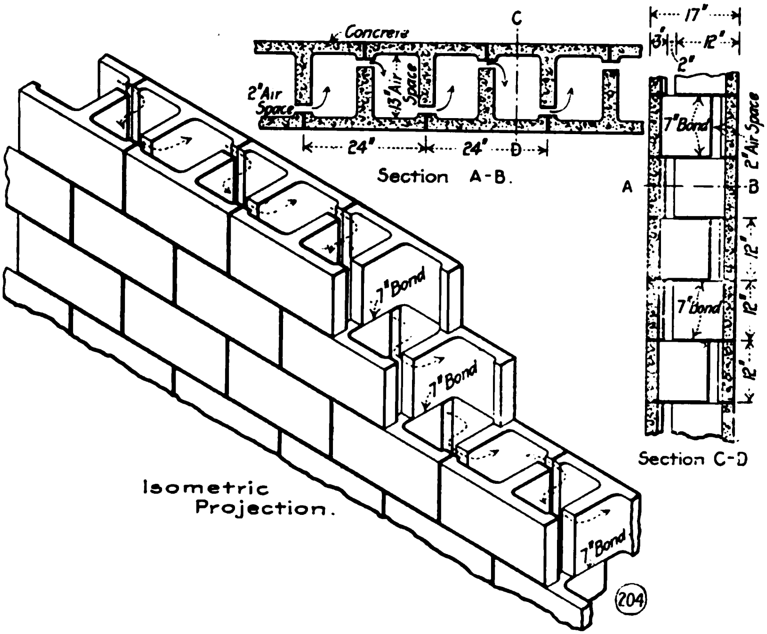


FIG. K. ILLUSTRATING CONTINUOUS HORIZONTAL AIR SPACE IN WALL BUILT ON AMERICAN HYDRAULIC STONE COMPANY'S SYSTEM.

MEMORANDA.

Memoranda and News Items are presented under this heading, with occasional editorial comment. Authentic news will be welcome.—ED.

The Charing Cross Disaster.—We are interested to observe that Major Pringle has now issued his report to the Board of Trade on the roof accident at the Charing Cross terminus. He has come to the conclusion that the fall of the roof was brought about by the breaking of a certain tie-rod, and that the fracture occurred at a weld, by reason of a flaw in the welding, this flaw commencing in the heart of the bar and gradually extending outwards. The additional weight of a temporary staging is ascribed as the immediate cause of failure, but as the total construction in tension at the time of the failure on the whole sectional area of the bar did not exceed 5·13 tons per square inch, Major Pringle does not consider that this stress was in any way unreasonable, and could not be anticipated to cause danger of failure.

The report also states that no reasonable precautions were neglected, and gives some words of warning as to the necessary precautions against welding flaws in roof construction generally.

The report, as an impartial one, by an independent authority of the highest standing, is of the utmost importance.

* * *

Accidents with Reinforced Concrete.—Our attention has been called to several accidents with buildings in reinforced concrete, attributed variously to either faults in design, of material or of workmanship. It is of the utmost importance that the true cause of any accident with reinforced concrete construction should be ascertained from independent sources, and for this reason we are collecting material wherever possible, through official channels, and would esteem it if any reader of this Journal would point out to us, either accidents that have come to their knowledge or any official reports on accidents that should claim our notice.

* * *

Fictitious Portland Cement.—We would also remind our readers that we are collecting data in respect to ficticious Portland cement, more particularly where the use of such unreliable material has resulted in an accident, and that any reliable particulars are welcome.

* * *

Reinforced Concrete at the International Congress of Architects.—We would remind all concerned that the discussion of Steel and Reinforced Concrete Construction at the impending Congress of Architects, is timed for 10 o'clock on Tuesday, July 17th, at the Grafton Galleries, when the subject is to be discussed (*a*) from its general aspect, (*b*) with special reference to the æsthetic and hygienic considerations in the case of very high buildings.

A paper is apparently to be presented on behalf of the Reinforced Concrete Committee and one by Professor Henry Adams. Other communications will be presented by Messrs. Wilemanns (Austria), Goodrich (America), Cloquet (Belgium), Bassegada (Spain), and Gaston Trélat (France).

The Congress Executive are to be congratulated upon having included this important subject in their Agenda paper, and it should be noted that this will be the only constructional question under consideration at the conference.

New Works in Reinforced Concrete.—Mr. L. G. Mouchel sends us an interesting list of new works in course of execution on the Hennebique system, including quays and jetties at Newcastle-on-Tyne; road work at Birmingham; bridges at Rochdale and Middleton; a reservoir at Nuneaton and a number of buildings, including factory work, for Messrs. Rowntree and Co., at York; warehouse work for the Associated Portland Cement Manufacturers, London; business premises and dyeing works at Dublin. The list is a most creditable indication of the progress that is being made by the Hennebique agency and its licensees. Of the last-named it is interesting to observe that many of the works on the list are being carried out by the Yorkshire Hennebique Contracting Company, Ltd, of East Parade, Leeds.

* * *

New Catalogues.—We have received several new catalogues of considerable interest having bearing on concrete and reinforced concrete construction, and amongst these we would specially mention one by the Patent Indented Steel Bar Company, Ltd., of Queen Anne's Chambers, Westminster, London, S.W. This catalogue is of quite extraordinary excellence and utility, not only as a description of the special system advocated by that firm, but in regard to the subject of reinforced concrete generally. It is indeed rare to find a catalogue so well prepared and carefully edited from the technical point of view as to be of truly instructive reading, and the firm in question and their engineers are to be congratulated upon this production.

We have received a catalogue from the Trussed Concrete Steel Company (Kahn System) of Caxton House, Westminster, London, S.W., which in a concise manner illustrates the principal features of their system and presents a number of interesting examples of work carried out by them in the United States. The catalogue is a very creditable production, and the calculations included will be found most useful.

The catalogue issued by the Armoured Constructions Company (Coignet system), of 43, Chancery Lane, London, W.C., is also a concisely prepared and well illustrated summary regarding the system and the works carried out in accordance therewith. Some foundations at the Bristol Docks are an interesting example of the application of the system in Great Britain. The other examples mainly relate to work in France. As an appendix to the catalogue some interesting memoranda are presented, entitled, "The rational proportioning of structures in armoured concrete."

Messrs. Vulcanite, Ltd., of 118, Cannon Street, London, E.C., have issued a well arranged catalogue on roof coverings for flat roofs, which should be of special value to those designing concrete flats which require some covering that will not crack, as is unfortunately frequently the case with asphalte coverings. The examples presented are nearly all British and cover a range of buildings going back some ten years, including examples of a most varied character—of very large factories on the one hand, down to rows of cottages on the other.

* * *

We have been requested to state that "Johnson" indented bars were used in the Thompson Norris Building, Cincinnati, illustrated on page 81 of our previous issue.

NEW WORKS IN CONCRETE

AT HOME AND ABROAD.

Under this heading reliable information will be presented of new works in course o construction or completed, and the examples selected will be from all parts of the world. It is not the intention to describe these works in detail, but rather to indicate their existence and illustrate their primary features, at the most explaining the idea which served as a basis for the design.—ED.

CONCRETE RIBBED ARCH FOOTBRIDGE OVER A GORGE.

The feature of particular interest in the Deer Park bridge, U.S.A., which has a 72 ft. span and measures 95 ft. over all, is the ribbed construction, which is clearly seen in the illustrations.

The Deer Park bridge has two ribs, with arch rings of 16 in. thickness, and varying in depth from 20 in. at the crown to 24 in. at the haunches. From the arch ring to the floor line there is a 7 in. spandrel wall, on which is carried the 4 in. horizontal floor slab. Between the ribs are a series of 6 in. diaphragms spaced 5 ft. c. to c., and extending from the floor line to the bottom of the arch ring. The office of these diaphragms is to take the wind load. Surmounting the floor is an open concrete hand railing.

The rise of the arch is 7 ft. 6 in. with a camber of 4 in., and the distance from the floor line to the level of the stream at the bottom of the gorge is 60 ft. The calculated live load was 80 lb. per square foot, and the test load was 100 lb. per square foot.

Each arch rib is reinforced by four 1 in. by 1 in. by 0·87 lb. steel T bars, located in the extrados and intrados of the rib. These bars are in four lengths; have wired splices, staggered, and are carried entirely through the abutting ends of the ribs on the walls of the gorge. Two U-shaped steel tees, 1 in. by 1 in. by 0·87 lb., constitute the reinforcement of each diaphragm, the horizontal arm of the U being imbedded in the diaphragm and the vertical arms running up through the ribs into the railing posts. In the floor there are eleven 1 in. by 1 in. by 0·87 lb. tees in each panel between diaphragms running transversely so as to secure a support on the ribs. There are also two short 1 in. by 1 in. by 0·89 lb. tees placed longitudinally in the plane of the ribs at the centre, and three flats, 1 in. by ⅛ in. running across the transverse floor tees the full floor length. The spandrel walls of the ribs were not reinforced. All intersections of steel work were thoroughly wired together.

The steel used was the ordinary grade of commercial steel. The concrete was hand-mixed with screenings and ⅞ in. broken stone, the composition of the mixture being 1–2–4. A 1 in. mortar finish was applied to the floor as a wearing surface.

The bridge, with the exception of the railing, was moulded in place. For this purpose a timber tower was erected in the canyon, as a centre support for heavy cross timbers, the other end of which rested on the canyon walls, from which also intermediate supports were run out as shown in Fig. 2. On these cross timbers vertical bents were erected, each composed of 2 in. by 4 in. sticks suitably braced, and varying in length according to the curve of the arch. Then came a double layer of 2 in. by 10 in. planks, lengthwise placed flat, with staggered joints, and on these a floor of 2 in. by 10 in. transverse planks. These latter were extended 4 ft. on each side to form a working floor upon which the outer vertical casings of the arch rings and spandrels were built, and also the inner casings of the arch rings at the proper distances apart. The outer casing being high, was braced at intervals by knee braces.

The concreting of the arch ribs was first completed, the work being begun simultaneously at both ends and applied in layers as usual. The inner casings of the spandrel wall and the floor form were next put in place, and the concrete for these parts was then applied. All casings and forms were plastered before any concrete was put in place, and surfaces exposed to view were spaded.

The principal advantage of the ribbed bridge is its economy. This is marked in structures larger than the Deer Park bridge, but in general averages from 25 to 35 per cent. for the same factor of safety. In highway and railway bridges, the ribs under the tracks can be made correspondingly heavier than the ribs under the roadway proper, thus realising still further economy. Other advantages are the adjustability of the structure under settlement, and the accessibility of all parts for inspection. There is some advantage due to the additional form of work, but the writer has made improvements which overcome this altogether, and still further simplify the construction and reduce the cost of this type of bridge.

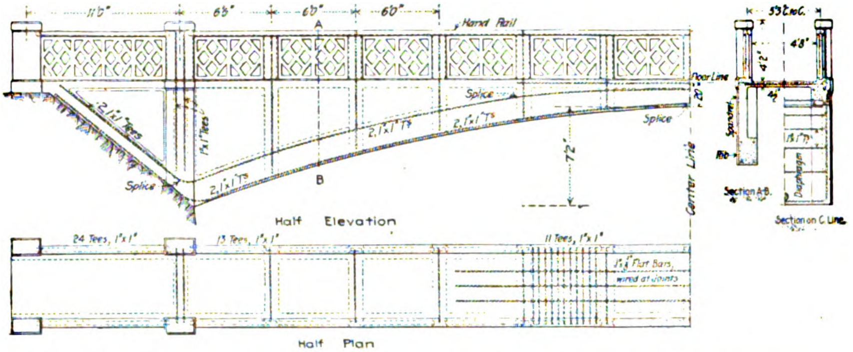


FIG. 1. HALF PLAN AND ELEVATION AND TRANSVERSE SECTION OF REINFORCED CONCRETE RIBBED ARCH BRIDGE, DEER PARK, LA SALLE, ILL.

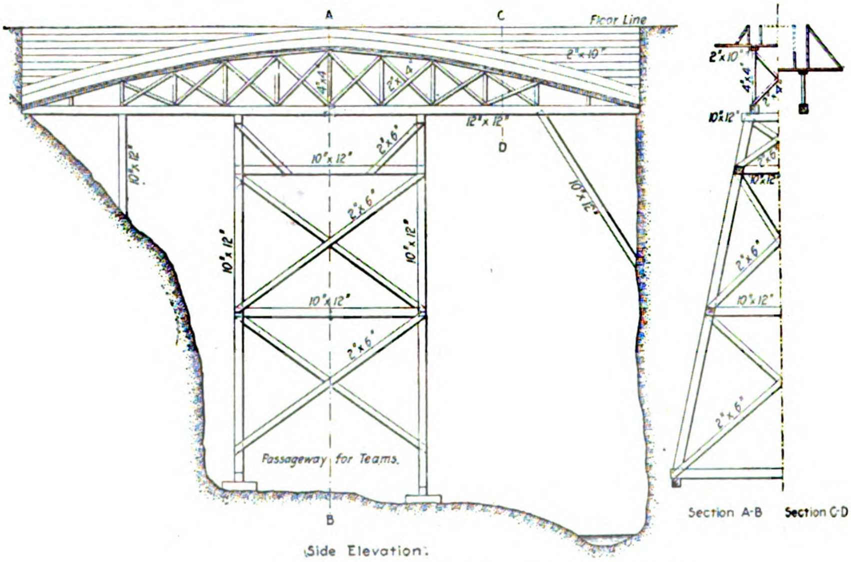


FIG. 2. CENTERS AND FORMS FOR DEER PARK BRIDGE

These improvements, together with the earlier improvements embodied in the Deer Park bridge, are covered by the writer's patents.

(*Engineering News, U.S.A.*)

The bridge was designed by Messrs. J. B. Strauss and Geo. Collis, of Chicago.

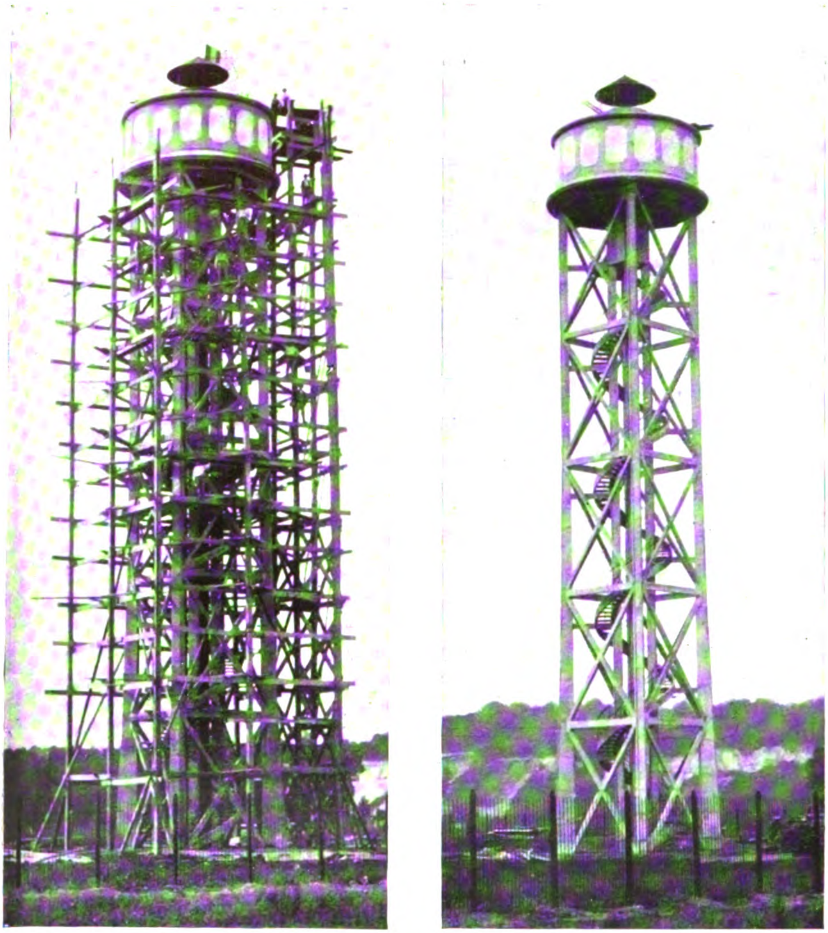
REINFORCED CONCRETE WATER TOWER, CHAMPAGNE-SUR-SEINE, FRANCE.

This is an example of one of the many small re-inforced concrete water towers which are becoming so popular in France, having regard to the economy of construction and the absence of expenditure for maintenance in painting. The example selected is from one by Messrs. Schneider's large works at Champagne-sur-Seine, the tank being intended to hold 100 cubic metres, and the height of the bottom of the tank being 33 metres or about 107 feet above ground level.

Mons. Friese acted as architect, and Messrs. Chassin, of Paris, carried out the work, also prepared the necessary details.

FIGS. 3 AND 4. REINFORCED CONCRETE RIBBED BRIDGE AT DEER PARK, U.S.A.

(Strauss and Collis Ribbed Arch System.)



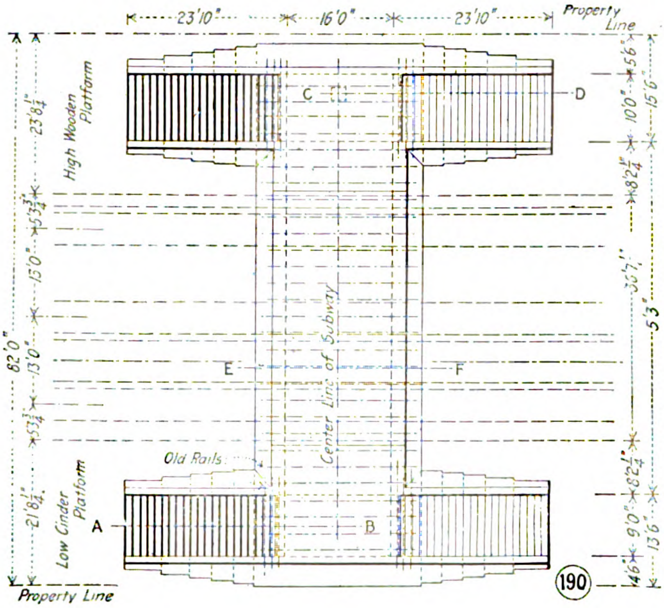
REINFORCED CONCRETE WATER TOWER AT CHAMPAGNE-SUR-SEINE, FRANCE.
(Chassin System.)

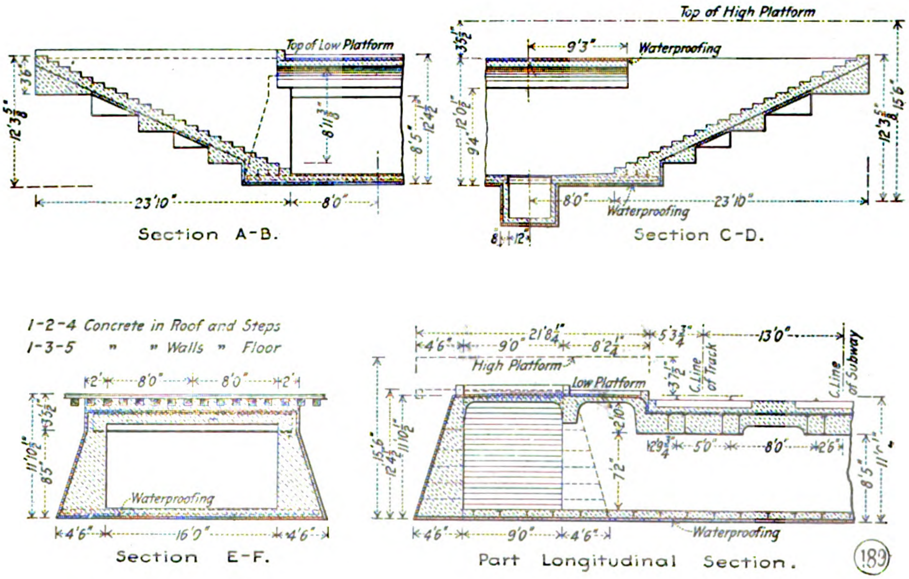
DIFFICULT WATERPROOFING OF A CONCRETE PASSENGER SUBWAY UNDER RAILWAY TRACKS.

The accompanying illustrations show a neat example of passenger subway construction under railway tracks, to which additional interest is contributed by the difficulties encountered in the waterproofing work. This subway gives passage to pedestrians under the tracks of the South Side R.R. at the Metropolitan Race Track at Jamaica, Long Island. *Fig.* 1 is a general plan of the structure and *Fig.* 2 shows the essential structural details. The entire structure is built of broken stone concrete strengthened in the roof by embedded steel beams under the rails; the mixtures used were 1-2-4 for the roof and stairs and 1-3-5 for the walls and floor. The plans were prepared under the direction of Mr. J. R. Savage, Chief Engineer, Long Island R.R., and the work of construction was in charge of Mr. David Beaver, assistant engineer.

The detail drawings of *Fig.* 2 show clearly the location of the waterproofing. It was in the placing of this waterproofing that the principal difficulties were encountered. The excavation for the subway was through gravel, and reached a depth of 11 ft. for the main subway and of 15 ft. for the sump. As the excavation proceeded several springs were encountered, the water from which, when allowed to rise, came up from 5 to 6 ft. above the subway floor and some 9 ft. above the sump bottom. The excavation was kept drained by pumps to a level below the subway floor. This floor consists of a layer of waterproofing embedded in mortar and covered by concrete reinforced by steel rails. The waterproofing layer consists of six layers of Hydrex waterproofing felt cemented together by hot Hydrex compound. On top of the waterproofing came a 1 to 2 in. coat of cement mortar and then the concrete proper.

The side walls were constructed of one course of brick, with struck joints on the inner surface, against which to apply the waterproofing, a new interlapping and reinforcing method, at the angle where the floor waterproofing and the wall waterproofing meet. These brick walls also





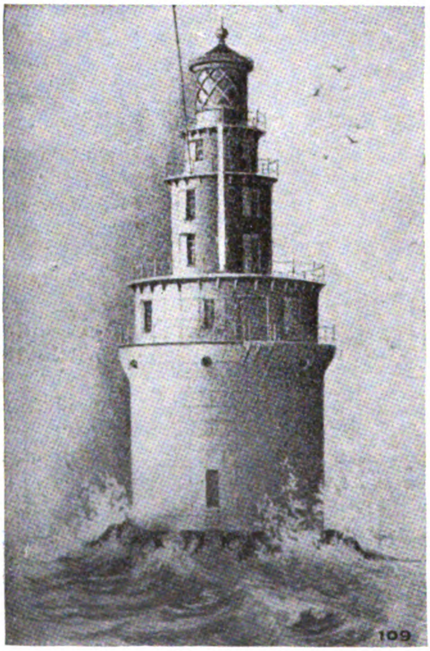
FIGS. 1 AND 2. CONCRETE PASSENGER SUBWAY ON LONG ISLAND, U.S.A.

served as one side of the form for the concrete of the walls proper of the tunnel. The floor and walls being completed, it was then a simple matter to construct the roof (jack-arches levelled off), over which the waterproofing was continued and covered with concrete, with sand under ballast on top, in which were set the ties and rails of the several tracks of the road passing over the tunnel. At one time during the construction, the earth, from weakening by water, fell in against and broke down the brick backing wall, taking the waterproofing with it and allowing the inrush of water to spread several feet over the bottom of the tunnel. This wall was built in 5 ft. heights at a time.

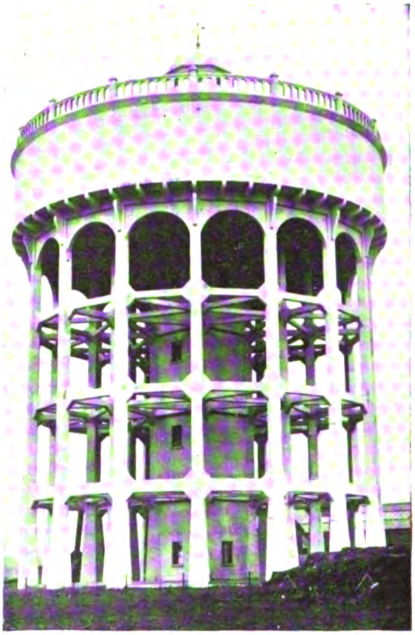
As indicating the water pressures, a labourer accidently punched with a crowbar a hole through the waterproofing stratum and the cement mortar covering, whereupon the water spouted up nearly 3 ft. The hole was successfully patched and covered with cement mortar and properly protected. When the tunnel was completed and the pumps stopped, the water rose from 5 to 6 ft. about the walls or 9 ft. from the bottom of the sump, and so remains. The structure, however, though completed some time ago, has been tight, with no percolation of water, and is satisfactory.

The waterproofing of the structure was designed by the Hydrex Felt and Engineering Company, of New York, N.Y., to whom we are indebted for the information from which this description has been prepared.

(*Engineering News, U.S.A.*)



A Concrete Lighthouse at San Francisco.

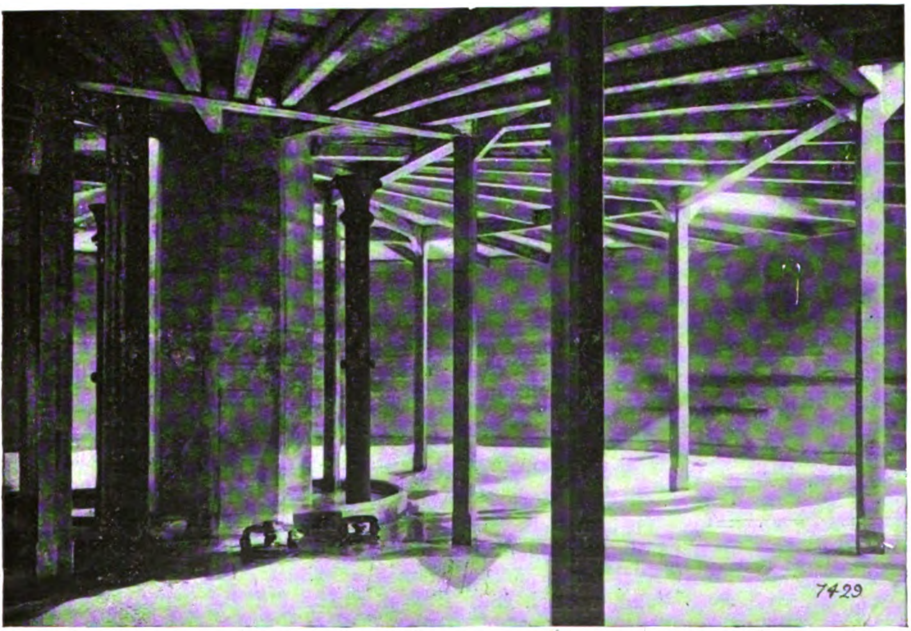


Water Tower at Newton-le-Willows.

PORTLAND CEMENT CONCRETE FOR LIGHTHOUSE CONSTRUCTION.

The "Mile Rock" Lighthouse, at the entrance of the San Francisco Harbour, a short distance from the "Golden Gate," and not far from the eastern shore, has been constructed in concrete. "Mile Rock" projected not more than 16 ft. above the mean sea level and at high tides was entirely submerged. At most only 1,000 square feet of surface was available after the rock had been levelled to some extent and only 704 square feet were secured as the foundation for the base of the light station.

This foundation was prepared elliptical in shape, being 40 ft. long by 25 ft. across. An immense steel shell was prepared and anchored to the main body of the rock, after which it was filled with reinforced concrete. When this layer had set, additional sections of the steel cylinder were added and filled in the same manner until the foundation was extended 40 ft. above the rock. Sixty tons of steel plating and 1,200 barrels of Portland cement were used in the foundation, which was the most difficult and hazardous

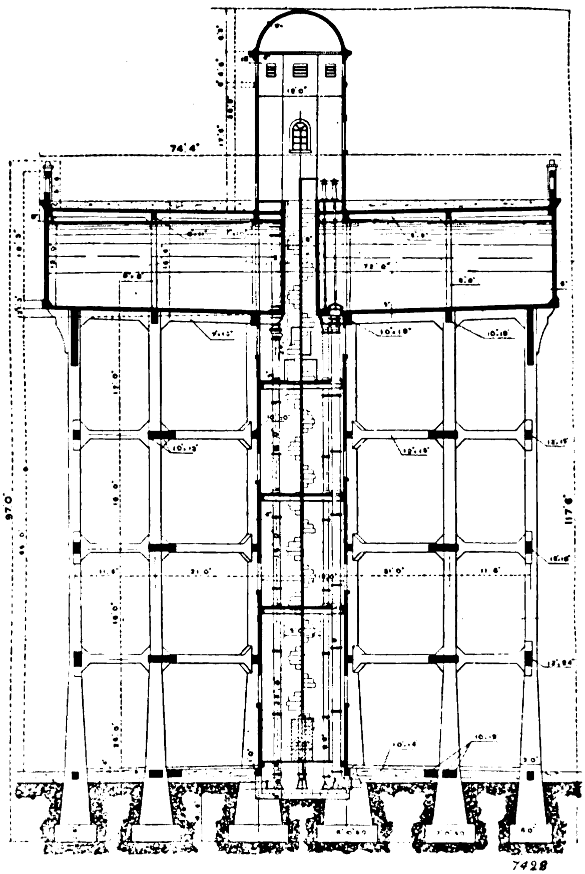


NEW WATER TOWER AT NEWTON-LE-WILLOWS.
(Hennebique System.)

part of the entire work. Above this a tower of 50 ft. was then built, surmounted by a third order light. From the mean sea level to the top of the tower is 92 ft. In construction of the section above the foundation an additional amount of 92 tons of steel were used. More than six months were required in building the foundation alone, and a year to complete the entire station. The total cost of the lighthouse was $100,000, *i.e.*, about £20,000. —(*Concrete*, U.S.A.).

NEW WATER TOWER AT NEWTON-LE-WILLOWS.

HENNEBIQUE'S SYSTEM OF FERRO-CONCRETE.



NEW WATER TOWER AT NEWTON-LE-WILLOWS.

The tank has a capacity of 300,000 gallons, and was built for the Urban District Council.

The reason a reinforced concrete tank was adopted was on account of the saving in painting and general maintenance in a district, which, owing to its chemical manufactures would undoubtedly have had a deteriorating effect upon an iron tank. It also saves a large amount of pumping over two miles of land, to the reservoirs, which it was first intended to build upon a hill, and the additional cost of the purchase of the necessary way-leaves for that purpose.

The tank is erected near a well 200 ft. deep, from which the water is pumped, and stands at a height of 80 ft. above the ground level, and it can be filled in about twelve hours. The foundations are formed of concrete blocks, and are carried down to the sandstone rock underlying the district about 10 ft. below the ground level, and on this the ferro-concrete legs or supports are started, the reinforced concrete legs being embedded about 6 in. into the concrete foundation. The legs are braced together with rings of horizontal braces, no vertical bracing being used in the structure. The centre of the structure is enclosed in concrete, forming a square shaft containing pipes and valves and a spiral staircase leading to the valve house at the top of the structure. The tank proper is 5 in. thick at the bottom, the sides at base 6 in. and is reduced at the top to 5 in. The tank was designed by Messrs. Read and Waring. Messrs. Cubitt's were the builders, the details of the reinforcement having been prepared on the Hennebique system.

For the two large photographs and section, we are indebted to *Engineering Review*.

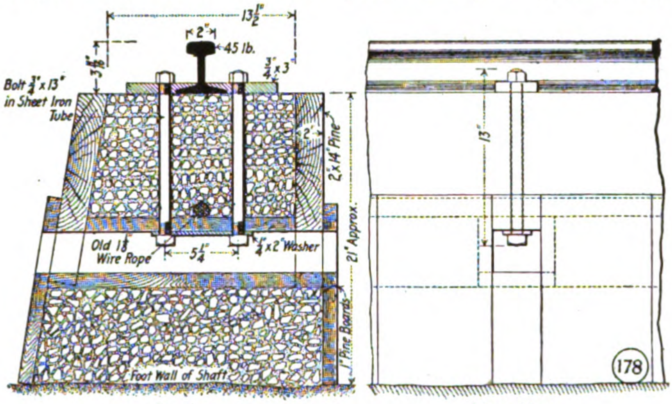
NEW USES OF CONCRETE

AT HOME AND ABROAD.

Under this heading reliable information will be presented as to new uses to which concrete and reinforced concrete are put, with data as to experience obtained during the experimental stage of such new applications of these materials. The use of reinforced concrete as a substitute for timber in exposed positions is one of the questions of the moment. Railway sleepers, telegraph posts, fence posts, etc., of concrete are being tried. Similarly, efforts are at present being made to prove that reinforced concrete is an excellent substitute for brickwork, where structures of great height are required.—ED.

CONCRETE STRINGERS FOR TRACKS IN MINE SHAFTS.

We illustrate herewith this interesting piece of work at the Ahmeek copper mine near Calumet, Mich. The shaft has a dip of 42 deg. from the horizontal, and by the cross section of the shaft, *Fig.* 1, it will be seen that there are two tracks of 4 ft. 6 in. gauge for the skips. Each of these has two lines of concrete stringers, *Fig.* 2, to which the 45-lb. rails are secured by clips and nuts on anchor bolts spaced 3 ft. apart. The bolts are threaded at each end, and pass through sheet iron tubes or sleeves which are placed in the forms before the concrete is deposited. The bottom nuts bear against a washer plate, while the upper nuts secure the rail clips, which, however, are now of slightly different form from those shown on the drawings. *Figs.* 2 and 3 show the construction of the moulds, which are in lengths of 15 ft.



Section

Elevation.

FIG. 2. CONCRETE STRINGERS FOR MINES, SHOWING MOULDS.

It was found in sinking the shaft that the average depth of stringer, measured at right angles to the dip of the shaft, was about 22 in. Before placing the moulds, all loose ground was removed from the foot-wall of the shaft, and after placing the moulds the foot-wall was washed down making a clean face inside the moulds for the concrete to rest on. These stringers have been in use about one and a half years and are giving good satisfaction. The concrete is composed of 1 part Portland cement, 3 parts sand, and 5 parts broken stone; the prices of material were $1.88 per barrel for cement, 73 cents per cubic yard for sand, and $1.13 per cubic yard for crushed stone. The total cost of 90 lineal feet of single track (two stringers) was $200.85, including all labour and materials (but not including cost of moulds). The average cost per lineal foot is $2.23, or approximately $4.46 per lineal foot for two tracks, or skip roads.

For drawings and information we are indebted to Mr. W. J. Uren, superintendent of the Ahmeek Mining Company, Calumet, Mich. He states that by this construction all timber work is dispensed with (except the dividers), thereby reducing the fire risk; and that as a rule the expense o equipping a shaft with concrete stringers will be less than that of timbering.

REINFORCED CONCRETE TOWERS FOR POWER TRANSMISSION LINES.

One of the most recent applications of reinforced concrete is to the construction of towers for carrying the conductors of electric power transmission lines, and we here present a few notes on the subject taken from an article in the *Engineering News* by Mr. Joseph Meyer, M.Am.Soc.C.E. of New York.

After discussing in detail the structural design of the steel towers largely used in such installations and the different types of concrete foundations for them, the writer points out that in France and Italy towers have been built of reinforced concrete in the shape of octagonal truncated pyramids with a large conical hole from top to bottom. The reinforcement consists of plain steel rods surrounded by wire wrapping, the transmission cables being carried on brackets not directly connected with the steel reinforcement. *Fig.* 4 shows a reinforced concrete tower for three strands for 60,000 volts and 400 ft. spans, which was designed for a proposed transmission line. The torsional strength of the tower depends mainly upon the concrete, and on this account it was considered advisible to space the cables as shown instead of in equilateral arrangement.

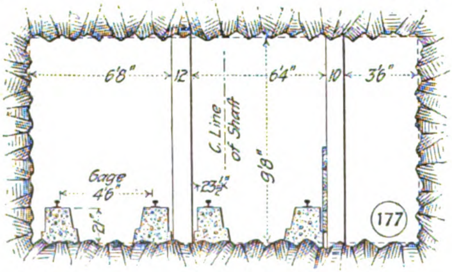


FIG. 1. CROSS SECTION OF MINE SHAFT.

Fig. 5 illustrates a four-post reinforced concrete tower with prismatic base for a three-phase power transmission line, this tower having been designed to comply with the following conditions: spans, 660 ft.; minimum clearance, 30 ft.; maximum deflection, 20 ft.; wind pressure, 660 lb. at each insulator and 40 lb. per vertical foot of tower; unequal pull, 1,000 lb. at one cable, or 667 lb. at each cable; assumed ice coating, ½ in. The materials per tower included, metal, 2,040 lb.; concrete (1 : 2 : 4 and 1 : 3 : 6), 5·8 cubic yards.

Reinforced concrete towers of small size,

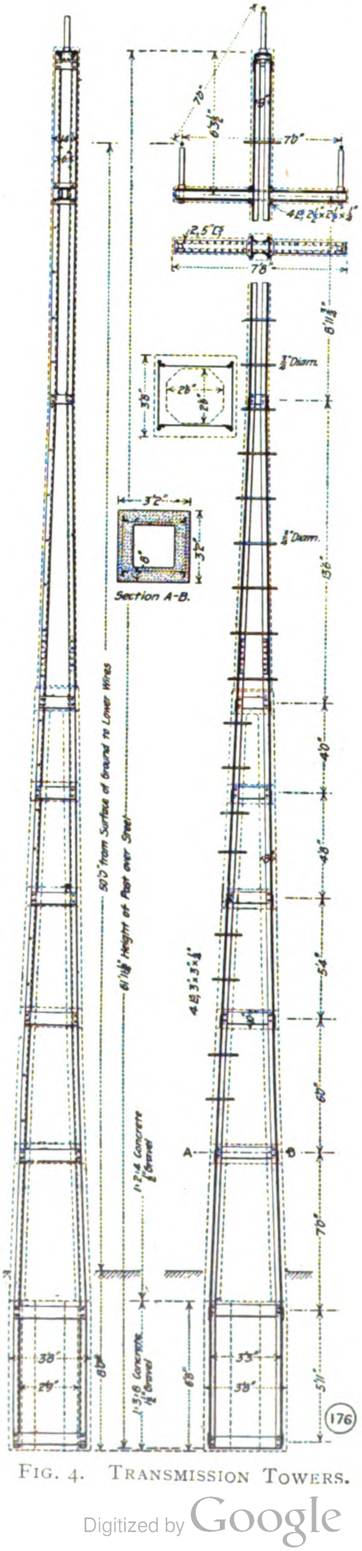


FIG. 4. TRANSMISSION TOWERS.

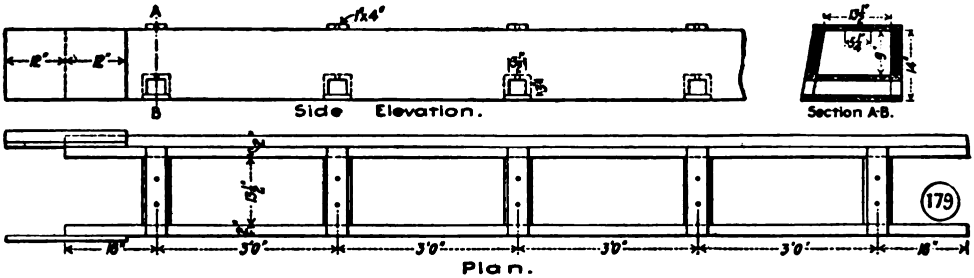


FIG. 3. CONCRETE STRINGERS FOR MINE SHAFTS.

such as have been built in France, can be manufactured at any suitable place and transported to the site for erection. The principal advantage of making the towers hollow is realised in the ease of transportation and erection, as solid towers could only be transported by rail and afterwards erected by the aid of a heavy derrick. The larger towers of the four-post type require a good road or railway for transportation, and when neither of these is available the towers must be built on the site.

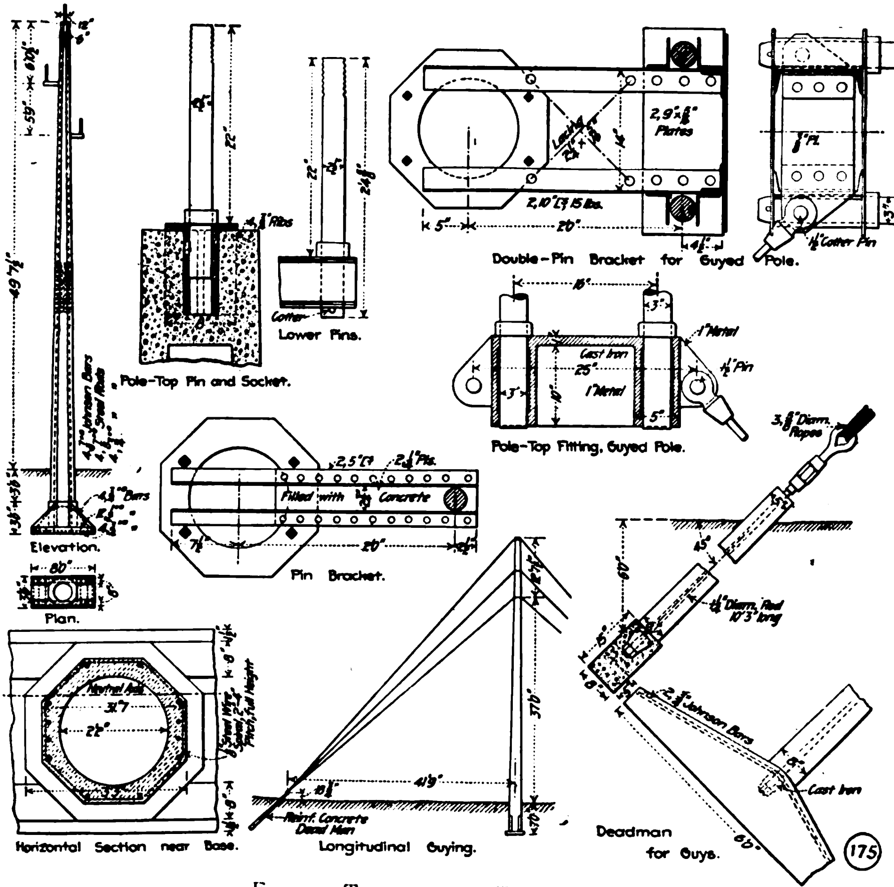


FIG. 4. TRANSMISSION TOWERS DETAILS.

TESTS WITH CONCRETE

AT HOME AND ABROAD.

We consider that the absence of reliable information as to the various tests carried out with concrete both at home and abroad has frequently led to misconceptions as to the qualities of this material, and we shall thus for the present accord considerable space to the presentation of authentic data that may be of service to those employing concrete in its various forms. The tests which will particularly call for our attention are those relating to strength, fire-resistance, and waterproofing.—ED.

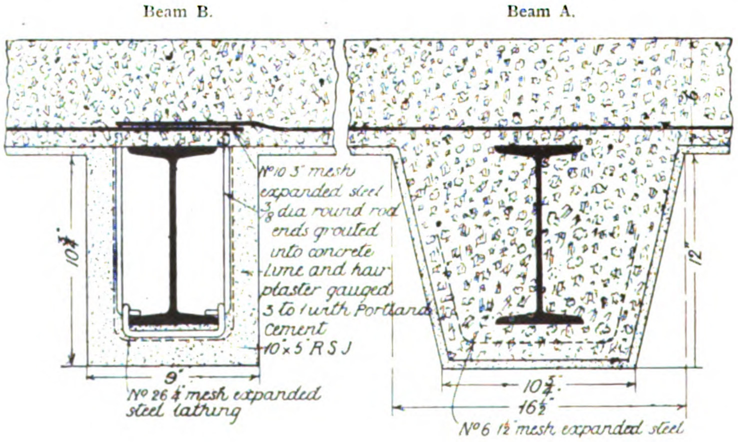
Fire Tests with Reinforced Concrete Floors.

The British Fire Prevention Committee are continuing their series of tests with reinforced concrete floors, and since our previous issue we have received two reports on floors constructed on the Coignet system and one constructed by the New Expanded Metal Company.

The two first-named reports require more space to deal with than is at our disposal in the current issue, and we must thus limit ourselves to stating that they afford striking evidence of the additional fire resistance afforded by a careful selection of the concrete aggregate and the value of the increased protection to the metal work in reinforced concrete beams.

The Expanded Metal Company's Floor.

This test was particularly interesting, owing to its firstly demonstrating the value of different forms of protecting girders supporting ordinary concrete slabs reinforced by expanded metal. Secondly, it demonstrated the efficiency of such slabs of suitable aggregate. We present sections of the forms of protection accorded to two girders supporting the floor, which details also show the position of the expanded metal lathing reinforcing the slabs.


Beam B.
Beam A.
No 10 3" mesh expanded steel
3/8 dia round rod ends grouted into concrete
lime and hair plaster gauged 3 to 1 with Portland cement
10"x5" RSJ
10¾"
9"
No 26 ¼" mesh expanded steel lathing
12"
10⅝"
16½"
No 6 1½" mesh expanded steel

The result of the test is practically that if brick concrete, comprising broken brick 2·66, sand 1·33, "ferrocrete" cement 1 (or a total of 4 of aggregate to one of "ferrocrete" cement), reinforced with expanded metal lathing be used in 7 ft. bays, no appreciable effect can be obtained by the combined application of fire up to 2,000 deg. Fahr., followed by water for five minutes from a steam fire engine. There were only a few slight cracks, none exceeding $\frac{1}{32}$nd of an inch in width. The deflection at the end of the test upon Beam A, *i.e.*, the solidly encased one, was under 1 in., whilst with the light Portland cement plaster casing (Beam B) it was 1¼ in. For particulars it would be well to refer to Report No. 109.

INDUSTRIAL ASSOCIATIONS

AT HOME AND ABROAD.

The various Industrial Associations interested in the components necessary for the application of concrete and constructional steel are, in many instances, so extremely well organised and have command of so much talent for the scientific aspects of their work, that their proceedings are an important factor in the development of the subject. Thus particulars will be published of such features of the meetings of bodies representing the steel and cement industries of the world as we hold may be of interest to our readers. The same applies to several of the more recently constituted associations representing the Concrete, Concrete Block, Artificial Stone and Steel Frame Building Industries of the United States and the Continent of Europe.—ED.

THE ASSOCIATION OF GERMAN PORTLAND CEMENT MANUFACTURERS.

Notes on the Meeting of 1906.

The 29th annual meeting of the Association of German Portland Cement Manufacturers was held in Berlin under the presidency of Herr Schott, of Heidelberg.

The Association's Laboratory.

Of the 84 different cements examined in this laboratory, only two failed to reach the standard required in the mechanical test. In the tests made with 1 : 3 briquettes after 28 days, the ratio of tensile to compressive strength was found to vary between the limits 1 : 17·7 and 1 : 8·3, the mean being 1 : 11·3, agreeing very closely with the value found in previous years. The highest percentage of lime found was 67·9, the lowest 58·6. Cements high in lime were found to show a high compressive, but low tensile, strength. Since a cement high in lime requires exceptional precautions to be taken in its manufacture to ensure a product which will not expand or crack after setting, and since so high a compressive strength is rarely called for, it is considered undesirable to allow the percentage of lime to approach the upper limit.

In connection with the carrying out of mechanical tests, the question has been raised, whether the mean of the ten samples should be taken, or whether any exceptionally low results should be rejected, as being due to defective preparation of the briquettes. In the Swiss tests, the mean of the highest six results is taken. Professor Martens, however, considers it necessary to take the mean of the whole of the results obtained. The question is to be examined further.

Dr. R. Dyckerhoff has studied the influence of an increase in the quantity of calcium sulphate in cements, and has come to the conclusion that a proportion corresponding with 2·5 per cent. SO_3 is without danger, whether the setting takes place in air or in water, but that any further increase is liable to cause expansion, if not cracking.

Time of Setting.

The committee appointed to investigate the time of setting and constancy of volume of cements, acting in harmony with the corresponding committee of the International Association for Testing Materials, has not yet obtained definite results. Professor Gary reported that the new apparatus for determining the time of setting, by recording photographically the height of the mercury column of a thermometer, was found to work satisfactorily, and to give useful information. Dr. Schindler has constructed an apparatus for determining the consistency immediately setting has begun, and finds it possible to obtain concordant results.

Revision of Standards.

The varying results obtained at different testing stations for tensile and compressive strength continue to be the subject of discussion. After a careful examination of the testing machines at eleven testing stations by the staff of the Lichterfelde Institution, the tests made on the same sample of cement made up under standard conditions still gave results varying from 19 to 31 kg. per square cm. for the tensile and from 163 to 224 kg. per square cm. for the compressive strength. In a second series of tests the same sand was supplied to each testing station, and new moulds were used The results of the compressive tests were now more uniform, but great variations were still found in the tensile determinations. The compressive test is therefore given the preference, and also corresponds more closely with the conditions of actual practice. Briquettes for the tensile test should be allowed to harden in air.

As regards the proportion of magnesia to be permitted, Dr. R. Dyckerhoff is of opinion that the upper limit should be 3·5 per cent. Herr Schindler and Dr. Michaelis, however, consider that a larger proportion, even amounting to 5 per cent., is without any bad influence. A new definition of Portland cement, taking into account the specific gravity, and the percentages of magnesia, sulphates, and flour, is suggested.

Admixture with Slag Cement.

Dr. Goslich reported on the present position of the slag-cement controversy. The experiments, begun in 1902 at the instance of the Prussian Minister of Public Works, were intended to extend over five years, and, no report will be issued before their completion. Dr. R. Dyckerhoff stated that cements containing slag harden under water like Portland cement, but yield inferior results when hardened in air ; it is, therefore, not desirable that the same specifications should be applied indifferently to the two materials.

A comparative series of experiments made in the Lichterfelde laboratory, showed that the difference was particularly marked in briquettes made up with sand in the proportions 1 : 3, 1 : 5, and 1 : 7, the slag cement invariably giving inferior results. A Portland cement to which 30 per cent. of fine sand or trass had been added gave in such mixtures results equal or superior to those given by slag cement without addition. When the full strength of a cement is not to be utilised, and cheapness is a consideration, it is therefore advisable to use Portland cement diluted with fine sand or trass, rather than slag cement.

Influence of Acid Water.

Herr H. Wehner discussed the influence of dissolved carbon dioxide and oxygen in water on iron and cement. Less than 10 milligrams of free carbon dioxide per litre causes the rusting of iron ; it is not uncommon, however, to find 30 or even 50 milligrams per litre in otherwise good waters. The carbon dioxide and bi-carbonates may be removed by the addition of lime or alkali. An apparatus was also described for removing dissolved oxygen and carbon dioxide by vigorous agitation under reduced pressure.

GERMAN CONCRETE ASSOCIATION.

The 19th annual meeting of the German Concrete Association took place in Berlin under the presidency of Herr E. Dyckerhoff of Biebrich.

Concrete Generally.

The important systematic investigation of concrete, planned by a committee of this association in conjunction with the Prussian Ministry of Public Works, has not yet been commenced. Interesting preliminary experiments have, however, shown that the nature of the aggregate, the quantity of water used in mixing, and the degree of ramming, are factors of equal importance with the proportion of the mixture. It is also recommended that tests should be made on the actual concrete, and not merely on the cement mortar, 28 days being allowed for setting. It is intended to examine concrete made with different kinds of broken and ground stone, as well as that made with natural sand and gravel. Professor Gary recommended that the present misleading descriptions of concrete mixtures should be abandoned, all mixtures being expressed in percentages.

Concrete Pipes.

Considerable discussion took place on the report of the committee appointed to draw up rules for the construction of concrete pipes, differences of opinion being manifested as to the necessity of specifying the placing of supports under the joints, of casting cement around the joints, and other similar questions. The rules as finally adopted will be published very shortly.

Reinforced Concrete.

An influential committee, under the presidency of Dr. C. von Bach, has undertaken to collect the present knowledge respecting reinforced concrete construction, and to carry out an extensive series of tests. In conjunction with the Union of German Architectural and Engineering Associations, it is proposed to draw up rules for this form of construction. The results already published, include experiments on the resistance of reinforced concrete decking, on the resistance of the embedded iron to slipping, (*see* No. 1 issue) on the elasticity of reinforced members, and on the compressive strength of columns with spiral reinforcement.

A number of typical structures in reinforced concrete were described by the engineers concerned, the papers being illustrated by means of photographs.

INDUSTRIAL NOTES.

These pages have been reserved for the presentation of articles and notes on proprietary materials or systems of construction put forward by firms interested in their application. With the advent of methods of construction requiring considerable skill in design and supervision, many firms nowadays command the services of specialists whose views merit most careful attention. In these columns such views will often be presented in favour of different specialities. They must be read as ex parte statements—with which this journal is in no way associated, either for or against—but we would commend them to our readers as arguments by parties who are as a rule thoroughly conversant with the particular industry with which they are associated.—ED.

REINFORCED CONCRETE CHIMNEYS.

By J. CARGILL.

There is about to be erected for the Associated Portland Cement Manufacturers, Ltd., at their Knight Bevan and Sturge Works, Northfleet, Kent, a large chimney of reinforced concrete, the contract for the erection of which has been placed in the hands of the Weber Steel-Concrete Chimney Company, Ltd., Queen Anne's Chambers, Westminster, with which the writer is associated.

The total height of this chimney from base of foundation to top will be 247 ft., diameter of flue is 8 ft. 6 in., and the foundation is 18 ft. square. The weight of the chimney, including base, is 868 tons.

Another large chimney of this type of construction is now in course of erection at Messrs. Abram Lyle and Sons, Ltd., sugar refinery, Plaistow Wharf, Victoria Works, London. This chimney has a total height of 261 ft., diameter of flue is 20 ft., and the base of foundation is 25 ft. square. A view is presented herewith showing the chimney in course of construction and at the same time showing five of the ten smaller chimneys it is about to replace.

Both of these chimneys are designed to withstand a wind pressure equivalent to a velocity of 110 miles per hour.

The Advent of the Reinforced Concrete Chimney.

Reinforced concrete is now an important factor in modern building construction, and excels by its indestructible nature any stone or brick masonry.

One of the most striking and interesting uses of reinforced concrete is its introduction into the construction of large chimneys, and during the past few years quite a number have been erected of this type of construction.

Their Advantages.

Among the advantages claimed for the concrete chimney is lightness of weight, thus conserving space or area necessary for a proper foundation. They are lighter in weight than self-supporting steel chimneys, including lining and foundation. The pressure on ground is from one-fifth to one-third that of a brick chimney. This is an advantage of the highest importance where the ground has a limited carrying capacity, necessitating the driving of piles or other foundation work of a special character which would increase the total cost of the chimney.

Reinforced concrete chimneys occupy a much smaller area than brick chimneys. Their foundations require about from one-fourth to one-third the area of a brick chimney of the same diameter of flue and height. This saving of space is often an advantage of the greatest importance in a modern power plant.

These chimneys, designed upon correct theoretical principles, are absolutely monolithic in character, being one solid single piece of stone from bottom to top. There are no mortar joints in their construction to permit leakage of air into the flue, which is detrimental to draught and economy; they are absolutely air tight.

The surface of the flue being smooth, minimises frictional resistance to the flow of gases and so ensures a higher efficiency than that of any other chimney.

They are erected in a shorter time than other chimneys, as there is no waiting for moulding and firing of purpose-made bricks. Steel, British Portland cement, sand and gravel are quickly obtainable in any locality.

The World's Highest Reinforced Concrete Chimney.

The highest and largest chimney in the world of this type of construction was erected last year at Butte, Montana, U.S.A., It has a total height of 352 ft. above ground level, with a flue diameter of 18 ft., which clearly shows that it is possible to build chimneys of unusual height and size of reinforced concrete. The base is only 42 ft. 6 in. square, and the total weight, including base, is 2,072 tons only.

Another large chimney of this type was erected last year at Tacoma, Washington, U.S.A. This chimney also has an inside diameter of 18 ft., and its total height above ground level is 307 ft. The foundation of this chimney is 39 ft. square, and the base of same is only 6 ft. 6 in. below the surface of ground. Total weight of this chimney, including base, is 1,659 tons.

General Description of a "Weber Chimney."

Logically and from an engineering standpoint, the first detail of chimney construction is the foundation.

The foundation of a "Weber Chimney" is comparatively light and made of concrete consisting of one part of Portland cement, two parts sharp and clean sand, and four parts of gravel. The steel reinforcement consists of two networks made of "T" steel. The meshes of these networks are different according to size of chimney and quality of ground and dimension of steel bars. The bars for the lower network are placed diagonally, and the bars for the second net about 4 in. to 6 in. above the first one,) are running parallel to the sides. By this method extra strong corners are formed. The vertical "T" bars, forming the reinforcement of the chimney itself, go down into the foundation.

The chimney itself consists of two distinct parts, the lower double shell part and the single shell part above, which are divided where the offset is to be seen.

The dimensions of these shells are different, the inside shell being with a very few exceptions 4 in. thick, while the thickness of the outer shell is depending upon the height of the chimney and varying between 6 in. and 12 in. In chimneys up to 175 ft. in height, 6 in. is the rule.

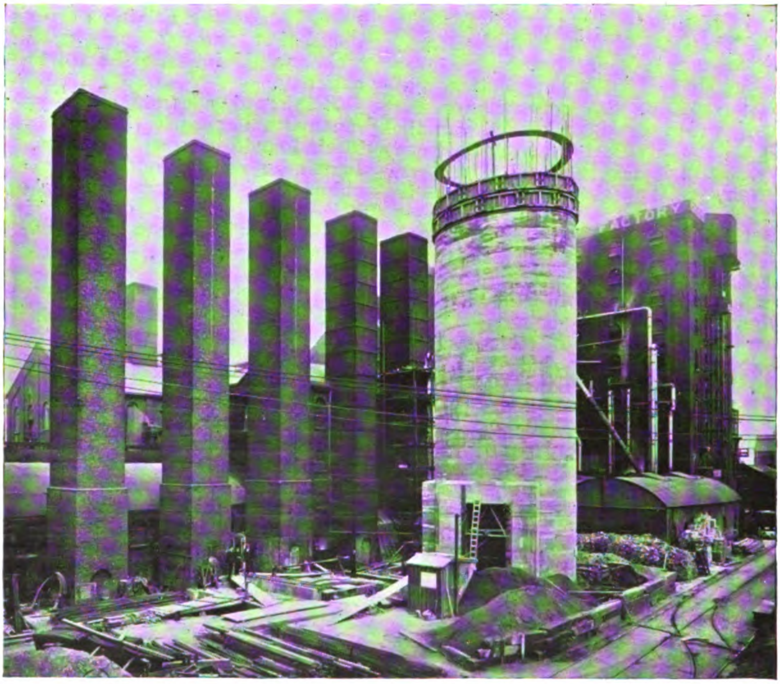
The thickness of the single shell is 4 in. to 8 in.

The height of the double shell is entirely dependent upon the purpose of the chimney, nature and heat of chimney gases, etc., and height of smoke entrance. For common steam boiler use we carry the double shell part about 30 to 40 ft. above the bottom of the smoke bridge; if not, local conditions require a different height.

Between the two shells in the lower part there is a circular air space of 4 in. thick.

The object of this arrangement is to have the inner shell, which has free space for expansion and contraction in every direction, shield the outer shell against the direct effect of the heat. The outer shell which takes up all the bending forces caused by wind pressure, etc., again protects the inner shell against the effects of the weather and temperature, thus preventing sudden cooling of same, and cracks which might be the result.

These arrangements also improve the draught conditions of the chimney considerably.



WEBER CONCRETE CHIMNEY IN COURSE OF CONSTRUCTION AT VICTORIA WHARF, LONDON.
(View showing 5 of the 10 chimneys at Messrs. Lyle's works, to be replaced by the Weber Chimney.)

The air-space is connected at the bottom with the atmosphere by means of little air inlets 3½ in. by 5 in. and at the top by means of the expansion joint with the chimney flue proper. This causes a draught in the air-space which keeps it clean from soot and ashes, and filling up of the air-space is thus prevented.

Inner shell, outer shell and air-space are absolutely circular and of even thickness all round. This assures even expansion and contraction and prevents cracks, which otherwise are unavoidable.

All the bending forces are taken up by the vertical "T" steel bars, forming part of the reinforcement. The resistance of the concrete itself is not taken into consideration by calculation. The concrete used in the chimney above the ground level consists of one part Portland cement and three or four parts of clean sharp sand. No gravel is used above ground level in these chimneys.

The vertical bars are of different dimensions from 1 in. by 1 in. by ⅛ in. to 1½ in. by 1½ in. by $\frac{3}{16}$ in. Weight and number of these bars is entirely dependent upon the dimensions of the chimney, wind pressure, etc.

We use the steel, in length from 20 ft. to 30 ft., and wherever the bars connect lengthwise a proper overlapping of not less than 24 in. is given. These joinings are made very irregular, preventing, if possible, getting too many joints at one height.

The vertical bars are at regular intervals encircled by steel rings properly bent in special bending machines. These rings are placed about 18 in. apart in outer and single shell, and also in the inner shell.

Although we prefer the use of "T" steel wherever possible, we are not limited to any form or shape, and, if desired, may use any shape of steel or other metal.

For office buildings, warehouses, etc., we build these chimneys with "all single" shell, while in short chimneys, which are exposed to exceptional heat, as for instance, glass works, brick kilns, etc., a double shell up to the top is preferable.

THE RATIONAL PROPORTIONING OF STRUCTURES IN ARMOURED CONCRETE.

A very common objection raised by engineers and architects in refusing to make use of reinforced concrete is that they are obliged to put themselves entirely in the hands of certain specialists, and that no data are furnished them by which they can check the adequacy of the proportions proposed. In order to obviate this objection the Armoured Concrete Constructions Company (Coignet system) have drawn up the following note, showing how the adequacy of the proportions suggested for any proposed construction in this material may be easily tested.

NOTE CONCERNING METHODS OF VERIFYING THE DIMENSIONS PROPOSED FOR ARMOURED CONCRETE WORKS ON THE COIGNET SYSTEM, WHICH MAY ALSO BE APPLIED TO ANY OTHER SYSTEM, IF THIS IS A RATIONAL ONE.

1. The mixture generally used for concrete in structures on the Coignet system is made in the following proportions :—

Three parts of Portland cement.
Five parts of river sand.
Ten parts of ballast (or broken brick, slag, or clinker). This mixture gives 12½ parts of concrete.

2. The weight of such concrete, including the usual percentage of iron, will be considered in the following verifications as equal to 156 lb. per cubic foot.

3. The cement generally used is artificial slow-setting Portland cement.

4. The compressive strength of such concrete is considered to be at least equal to 2,225 lb. per square inch. In the following calculations, in order to allow of a sufficient margin of safety, 635 lb. per square inch is considered a maximum for the fibres bearing the greatest stress in the deflected body. This figure corresponds to a factor of safety of 3½. The average resistance of such bodies is, of course, much less than the maximum stress on the outer fibres, and is about : $\frac{635}{2}$ for the slabs, and generally rather more for the beams.

5. For the framework, mild steel is used which has a tensile strength of 58,000 lb. per square inch with an elongation of 22 per cent. on 8 in. In order to reach the same factor of safety as above—viz., 3½—the maximum tensile working strain will be considered in the following verifications as 16,600 lb. per square inch.

6. The strain on the framework when ordinary iron is used should not exceed 13,800 lb. per square inch.

7. We assume that the modulus of elasticity of concrete, E , is constant for every load, and that the proportion between the modulus of elasticity of steel, E_s, and the latter is

$$\frac{E_s}{E_c} = n = 15.$$

8. The tensile strength of concrete must be entirely neglected in the following verifications ; consequently in bodies which are only subjected to tensile stresses, such as pipes and cylindrical tanks having an internal pressure, the work done by the armatures must alone be taken into consideration, taking the safe stress as at the rate of 16,600 lb. per square inch for steel, and 13,800 lb. per square inch for iron.

Example : Let us calculate, for instance, the working stress of the armatures of a cylindrical tank (*Fig.* 1) the diameter of which is equal to 30′, with a height of water of 14′. The circular bars in the lower part of the tank are spaced at the rate of 4 per foot run, and have a diameter of ½″ each.

$$\text{Tens. str.} = 14' \times 62{\cdot}28 \text{ lb.} \times \frac{30'}{2} = 13{,}080 \text{ lb.}$$

Section of bars per foot, 0·784 square inch.

$$\text{Working stress on bars} = \frac{13{,}080}{0{\cdot}784} = 16{,}600$$

lb. per square inch.

9. As we do not take into account the tensile strength of concrete, deflected bodies in armoured concrete may be considered in the following manner :—

Slabs, or beams not monolithic with a slab, can be reduced to the compressed part (see *Fig.* 2), the width of which is a and the thickness of which is d, and to a section of bars s equal to the total section of the framework embedded along the width a. The height h of this body is equal to the total height H minus the small part u of the concrete situated below the axis of the framework.

Beams combined with slabs may be considered in the following manner :—

The compressed part to be equal to or smaller than the depth E of the slab, and at a stretched portion equal to the total section of the bars embedded in the lower portion of the beam. Here, also, the height we have to take into consideration is the total height H minus the part of concrete u situated underneath the axis of the bars (see *Fig.* 3).

10. In the case of beams combined with a slab we cannot take into account in our calculations the whole width of the slab between two consecutive beams. We must only consider a fraction of this width as efficacious.

This fraction is determined by the formula— $a = l\left(1 - \frac{l^2}{L^2}\right)$,

in which l is the width of the slab, and L the span of the beams.

Example : If we have, as in *Fig.* 4,

$$l = 8' \qquad L = 20'$$

$$\frac{l}{L} = \frac{8}{20} = 0{\cdot}4$$

$$\frac{l^2}{L^2} = 0{\cdot}4^2 = 0{\cdot}16$$

$$a = 8'\,(1 - 0{\cdot}16) = 0{\cdot}84 \times 8' = 6{\cdot}72'.$$

Of course, this formula cannot be applied when the proportion $\frac{l}{L}$ becomes greater than ½. In that case we cannot take the efficacious width of the slab to be more than 0·75 of a. Therefore the above ratio is comprised between ¾ and 1.

11. The methods used in calculating the proportions of armoured concrete are the same as those used for homogeneous bodies, but with the following restrictions :—

(1) That we do not take into consideration the concrete subjected to tensile strains.

(2) That we replace the section of principal bars (those running in the direction of the span) by a section of concrete n times larger (or 15 times larger), or, expressed otherwise, a section $n\,s$, in accordance with what we have said concerning the proportion existing between the modulus of elasticity of steel and concrete—viz. ;—$n = 15$.

12. *Direct Compression.* — The working stress on the concrete and that on the longitudinal bars will be found by the following formula, in which S indicates the section of concrete, s the total area of the bars, and P the central vertical load.

Working stress on concrete per square inch

$$r = \frac{P}{S + n\,s} = \frac{P}{S + 15\,s}.$$

Working stress on bars per square inch

$$R = n\,r = 15\,r.$$

Example : What is the working stress on the concrete and on the bars in a square pillar 20″ by 20″, with a framework of four longitudinal bars, 1⅛ in. in diameter, supporting a load of 125 tons ? (See *Fig.* 5.)

$P = 125 = 28{,}000$ lb.

$S = 20'' \times 20'' = 400$ square inches.

$n\,s = 15 \times 4 \times 0{\cdot}994 =$ about 60 sq. inches.

$r = \frac{28{,}000}{400 + 60} = 610$ lb. per square inch.

$R = 15 \times 610 = 9150$ per square inch.

For a post higher than twenty times the side of the square section or smallest dimension of the post, we should not be justified in taking the maximum value of 635 lb. for the concrete working in compression, but only a fraction of this, as indicated by Rankine's or Euler's formula.

13. *Bending.*—The position of the neutral axis of a slab (see *Fig.* 6) is given by the equation $a\,d \times \frac{d}{2} = n\,s\,(h-d)$ (1). The depth d of the compressed concrete, or rather, the proportional depth, $\frac{d}{h}$ depends only on the section s of the bars when the value attributed to n is given. When we have determined this value of d we know the lever-arm Z of the resisting couple, the centroid (point of application of the resultant of the compression) lying at the centre of gravity of the triangle A B C—that is, at a distance $\frac{d}{3}$ from B C—we have, therefore $Z = h - \frac{d}{3}$.

If we call M the moment of the external forces, and F the thrust or pull of the resisting couple, we have $F = \frac{M}{Z}$.

The average working stress on the concrete will be

$$\frac{r}{2} = \frac{F}{a\,d}$$

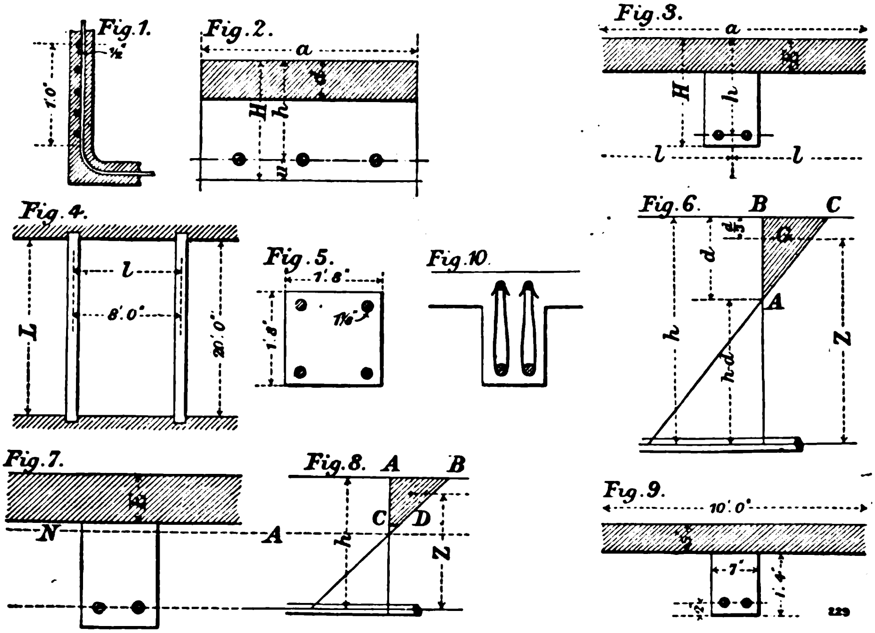
or

$$r = \frac{2\,F}{a\,d}.$$

And the working stress on bars, the section of which is s, is $R = \frac{F}{s}$.

14. *Average Position of the Neutral Axis in Slabs.*—In order to simplify this verification we may suppose that Z is approximately equal to $0{\cdot}88\,h$. In fact, if we suppose a percentage of iron of 0·5 per cent., the equation (1) gives us $\frac{d}{h} = 0{\cdot}31$; and if we suppose 1 per cent., we have $\frac{d}{h} = 0{\cdot}42$.

The average value of $\frac{d}{h}$ is therefore about 0·36, and therefore the average value of $Z = 0{\cdot}88\,h$.



FIGS. 1 TO 10. DIAGRAMS TO THE COIGNET NOTE.

Example: Let us verify a slab 3¾ in. thick, with two bars and a quarter per foot, each ⅜ in. in diameter, with a span of 8 ft. 3 in., and a superimposed load of ¾ cwt.

(One cubic foot of armoured concrete = 156 lb.)

Dead-weight per sq. ft. = $3\frac{3}{4}'' \times \frac{156\text{ lb.}}{12}$	= 49 lb.
Applied load = ¾ cwt. per sq. ft.	= 84 lb.
Total load per square foot ...	133 lb.

$$M = \frac{133 \times (8'\,3'')^2}{10} = 905 \text{ foot pounds.}$$

We can use the formula $M = \frac{p\,l^2}{10}$ when the slab is monolithic with an armoured concrete beam, assuming that it does not rest freely upon the walls, but that it is fitted into the latter or secured on the supports. If, however, this beam rests freely upon its supports, we have to use the formula $M = \frac{p\,l^2}{8}$,

as h is equal to $E - u = 3\frac{3}{4}'' - \frac{3}{4}'' = 3''$.

$$Z = 0{\cdot}88\,h = 0{\cdot}88 \times \frac{3}{12} = 0{\cdot}22.$$

$$F = \frac{905}{0{\cdot}22} = 4120 \text{ lb. per foot wide.}$$

$$d = 0{\cdot}36\,h = 0{\cdot}36 \times 3'' = 1{\cdot}08''.$$

$$a\,d = 12 \times 1{\cdot}08 = 13 \text{ square inches.}$$

$$\frac{r}{2} = \frac{4120}{13} = 317 \text{ lb.}$$

$$r = 2 \times 317 = 634 \text{ lb.}$$

$0{\cdot}18$ = section of one bar ⅜ in. in diameter.

$$s = 2\tfrac{1}{4} \times 0{\cdot}18 = 0{\cdot}248 \text{ square inch.}$$

$$R = \frac{4120}{0{\cdot}248} = 16{,}600 \text{ lb. per sqare inch.}$$

15. *Beams in Combination with a Slab* (*Figs.* 7 and 8).—In order to make an accurate verification here we must determine the position of the neutral axis by formula (1) and the lever arm Z of the resisting couple by geometrical considerations. In other words, we have only to ascertain for that purpose the position of the centre of gravity of the trapezium A B C D (*Fig.* 8) corresponding to the depth E of the slab, when, as usually happens in beams, the neutral axis is situated slightly below C D. In the same manner, the average

working stress on the compressed concrete can be ascertained by geometry. It is equal to $\frac{AB + CD}{2}$ (*Fig.* 8). In order to simplify this verification, we may assume that the neutral axis coincides with C D, and then we have

$$Z = h - \frac{E}{3},$$
$$F = \frac{M}{Z},$$
$$R = \frac{F}{s},$$
$$\frac{r}{2} = \frac{F}{a \times E}.$$

Example: Let us verify a beam width 7″, depth under slab 16″, $u = 2''$; framework, two bars, 1¾″ in diameter; span = 22′ (*Fig.* 9); distance between beams equals 10′ centres; superload, 1 cwt. per sq. ft.; depth of slab, 5″.

$$\text{Dead-weight of slab } \frac{5''}{12} \times 10' \times 156 \text{ lb.} = 650 \text{ lb.}$$
$$\text{Superload } 10' \times 112 \text{ lb.} \qquad = 1120 \text{ ,,}$$
$$\text{Dead-weight of beam } \frac{7}{12} \times \frac{16}{12} \times 156 \text{ lb.} = 121 \text{ ,,}$$
$$\text{Total load per foot} \quad \ldots \quad \ldots \quad 1891 \text{ lb.}$$
$$M = \frac{1891 \times (22')^2}{8} = 114{,}406 \text{ lb.}$$
$$h = 16 + 5 - 2 = 19''$$
$$Z = 19 - \frac{5}{3} = 17{\cdot}33'' = 1{\cdot}44'$$
$$F = \frac{114{,}406}{1{\cdot}44} = 79{,}500 \text{ lb.}$$
$$s = 2 \text{ bars } 1\tfrac{3}{4}'' = 4{\cdot}81.$$
$$R = \frac{79{,}500}{4{\cdot}81} = 16{,}500 \text{ lb. per square inch.}$$

To compression:— $\frac{l}{L} = \frac{10}{22} = 0{\cdot}455$

$$a = 10'(1 - 0{\cdot}455)^2 = 7{\cdot}94'$$
$$\frac{r}{2} = \frac{79{,}500}{7{\cdot}94 \times 12 \times 5} = 166 \text{ lb.}$$
$$r = 2 \times 166 = 332 \text{ lb. per square inch.}$$

These two last verifications are only approximate, but the actual resulting strains are always smaller than thus calculated.

16. *Shearing Stresses.*—Besides the tensile and compressive stresses we have also to consider shearing stresses. It is admitted for the slabs, which have a comparatively large section of concrete, that stirrups are not necessary. This, however, cannot be assumed in the case of beams in combination with a slab, and nearly all specialists assume in their calculations that one-half of the shearing stress can be supported by the concrete, and the other half by the stirrups.

Let us call D the spacing between the stirrups, and T the average shearing stress in the portion of the beam considered, s the section chosen for the stirrups or any other transversal framework, Z the lever arm of the resisting couple, then the stress on the stirrups, in order to equilibrate the corresponding shearing stresses, will be $R = \frac{\frac{T}{2} \times D}{Z \times s}$, and the same intensity of working stress is assumed as in the case of the longitudinal principal bars.

Example: In the annexed example we have assumed two stirrups having two bars each $\frac{3}{16}$ths diameter, and their spacing at the points of support is 2 in. (*Fig.* 10).

We wish to find the working stress on these stirrups. The shearing stress reaches its maximum at the points of support and is equal to

$$T = \frac{1891 \times 22'}{2} = 20{,}800 \text{ lb.}$$

In accordance with what has already been stated above we will let the stirrups bear half the strain,

$$\frac{20{,}800}{2} = 10{,}400 \text{ lb.}$$

The section s of the stirrups is therefore equal to $2 \times 2 \times 0{\cdot}028 = 0{\cdot}112''$.

Therefore

$$R = \frac{10{,}400 \times 2''}{17{\cdot}33 \times {\cdot}112} = 15{,}800 \text{ lb. per square inch.}$$

BOOKS RECEIVED.

Arrangements are being made by which it is hoped that it will be possible to present a record of all books on reinforced concrete, concrete, steel frame buildings, cement and steel, published at home and abroad, and of these the more important ones will be summarised and reviewed on somewhat novel lines. We had intended commencing the reviews in the current issue, but owing to lack of space, it has been necessary to postpone our reviews to a further issue.

In the meantime, we desire to generally acknowledge receipt of numerous books from publishers at home and abroad.

* * * *

Owing to lack of space the sections entitled Research Work, Laws, Rules and Regulations and Correspondence have been deferred to a later issue.

ARTICLES AND PAPERS

AT HOME AND ABROAD.

The following articles and papers are among the most important published at home and abroad during the second quarter of 1906 :—

I.—CONCRETE CONSTRUCTION.

Articles.

Concrete Building Blocks.—*Zement u. Beton*, 15.3.06.

Foundations of Large Concrete Blocks.—*Zement u. Beton*, 15.3.06.

Concrete Pavements in Denver : owing to the successful experiments carried out by Mr. C. A. Trease, engineer to the Denver City Tramway Company, the Board of Public Works have decided to pave a number of alleys in concrete, a description of the works being given in this article.—*Eng. Rec.*, 31.3.06.

Recent Improvements in Piles : an *ill.* description of the latest types of the Simplex concrete piles, detailing methods of sinking and construction, and giving the loads which have been sustained by these piles without settlement.—*Engineer*, 13.4.06.

The Surface Finish of Concrete Masonry : in the construction of concrete bridge masonry in Philadelphia, the process used for finishing the surface consists merely in removing the face moulds while the concrete is still friable and washing the surface of the concrete with water. To secure a uniform colour and complete flushing of the exposed faces, a so-called granolithic mixture is applied in the mould to a nominal thickness of 1 in., just ahead of the body concrete, which is placed against and rammed into it, thus securing a perfect bond between the face and the body. This granolithic mixture is a fine concrete composed of one part cement, two parts sand, and three parts granolithic grit. The article describes the manner in which the face moulds should be constructed to make the surface accessible for washing at the proper time, and gives directions for performing the operation of washing in the most effective manner.—*Eng. Rec.*, 28.4.06.

Concrete and Concrete Block Sewers in St. Joseph, Mo. : describing various extensions made to the sewerage system, which carries the combined domestic and storm-water flow into the Missouri River. These works exemplify construction in plain concrete, reinforced concrete, and concrete blocks. The largest of the new conduits is of elliptical shape, the major axis at it mouth measuring 17·5 ft.—*Eng. Rec.*, 5.5.06.

The Three-hinged Concrete Arch Bridge, Cleveland, O. : recently opened for traffic over Big Creek in Brookside Park, Cleveland, is said to enjoy the distinction of being the first three-hinged concrete arch bridge hitherto constructed in the United States, and also of being the flattest semi-elliptical arch ever built. It is a plain concrete arch without longitudinal reinforcement, with a rise of less than one-tenth of the span, and has steel hinges at the crown and the haunches to take up any arch ring movements. The care bestowed on the design of the structure was clearly shown at the time when the centres were struck, by the almost entire absence of deflection. The last upright posts in the centering were knocked out almost as easily as the first that were removed, thereby proving that the arch had taken all its own strains before the centres were struck. This is quite exceptional in a concrete arch where the falsework is removed in cold weather, as in this case, because the concrete is then in its extreme contraction. In this bridge the deflection at the crown was only 0·05 in. greater than was computed for temperature variations, shrinkage of the concrete due to setting in air, and the shortening due to axial compression. The concrete—composed of Portland cement, silicious lake sand in the proportions of 1 : ½ : 5, and crushed stone—was very carefully mixed, promptly placed in the moulds and thoroughly tamped in place.

The Pedlar River Concrete Block Dam, Lynchburg Water Works : contains a full account of the dam under construction in connection with a new water supply of about 8,000,000 galls. of water daily for Lynchburg, Va. The dam, which is being built across the Pedlar River, is about 500 ft. long on the crest and has a maximum height of 73 ft. 6 in. The concrete work is of special character in the respect that it consists of rectangular blocks moulded in position, with dimensions varying from about 20 to 90 cubic yards each. The dam was commenced in July, 1904. *Ill.—Eng. Rec.*, 12.5.05

II.—REINFORCED CONCRETE CONSTRUCTION.

Articles.

The Design of Concrete-steel Beams and Slabs. By Mr. Edward Godfrey : setting forth the principles of design and suggesting simple formulæ and unit stresses for the design of concrete-steel beams and slabs.—*Eng. News*, 15.3.06.

The North-Western Ohio Bottle Company's Factory : comprises a main building 142 ft. by 140 ft. and a coal shed, both constructed of reinforced concrete. *Ill.—Eng. Rec.*, 24.3.06.

Reinforced Concrete Tramway Depot at Nuremberg. By Dipl.-Sug. Supt.—*Deut. Bauzt.*, 28.3.06.

The Prevention of Coast Erosion : The third article of a series by Dr. J. S. Owens, A.M.Inst.C.E., describing and *ill.* various types of groynes, among which the only one possessing features of novelty is a groyne recently designed by the writer. It consists of reinforced concrete piles, each having a deep groove down two opposite sides, so that a reinforced concrete slab can be inserted in the grooves between each pair of adjoining piles. The reinforcing bars of the piles are so arranged and tied together as to thoroughly support the jaws of the grooves against the pressure of the slabs, which in turn are reinforced so as to resist pressure from either side.—*Eng. Rec., Apr.*, '06.

Calculations of Columns with Spiral Reinforcement. By Dipl.-Ing. Sor.—*Beton u. Eisen, Apr.*, '06.

Calculation of Columns with Spiral Reinforcement. By N. de Tedesco. *Ill.—Le Ciment, Apr.*, '06.

Causes of Rupture of Reinforced Concrete Beams. By Dr. M. R. von Thullie.—*Beton u. Eisen, Apr.*, '06.

Roof of a Turbine House at Chevres, Geneva : the iron roof of the power house, having been completely destroyed by fire, has been replaced by a reinforced concrete roof, full detailed drawings of which are given. *Beton u. Eisen, Apr.*, '06.

Loading Test of a Reinforced Concrete Floor in the Skrivan Sugar Factory [Bohemia]. By K. Rössle.—*Beton u. Eisen, Apr.*, '06.

Protection of Reinforced Concrete Buildings from Lightning. By A. Kleinloge : buildings constructed entirely in reinforced concrete do not need the provision of lightning conductors, the charge being dispersed by the reinforcement.—*Beton u. Eisen, Apr.*, '06.

The Reinforced Concrete Failure at Atlantic City, N.J. : much controversy has arisen among the various concrete interests as to the reason for the failure of the reinforced concrete work during construction at Reed's Bathing Establishment at Atlantic City. This article discusses the remarkable combination of conditions responsible for the collapse. Briefly summarised, the suggested causes of the failure were : (1) Gross carelessness in the concreting of the beams ; (2) disintegration of concrete owing to frost ; (3) lack of cohesion between the beams and floor slabs ; (4) the use of different types of concrete in beams and floor slabs respectively ; (5) reinforcement not properly designed especially that for withstanding shear ; (6) poor character of the brick-

Reinforced Concrete Construction—*Continued.*

bearing walls, and the absence of bond between the two outer courses of brickwork.—*Eng. News*, 5.4.06.

Roofing Panels of Reinforced Concrete.—*Zement u. Beton*, 15.4.06.

Reinforced Concrete Sand Bins: describing the construction of a group of four cylindrical sand-storage bins, 40 ft. high by 22 ft. 9 in. internal diameter with a collective capacity of 2,200 cubic yards. *Ill.*—*Eng. Rec.*, 21.4.06.

The Overflow of the Colorado River and the Salton Sea. II. By George Wharton James: an *ill.* article containing a description of the permanent reinforced concrete regulator, with openings capable of passing 7,000 cubic feet of water per second, now under construction for controlling the waters of the Colorado river. The structure is 185 ft. wide by 26 ft. high above the sill, being composed of twelve reinforced concrete cells, about 16 ft. wide by 14 ft. high, which will be filled with rock, gravel, and sand to make the construction stable, and to enable it to withstand the pressure of heavy floods.—*Scient. Am.*, 21.4.06.

Barrel and Cross-Vaulting in Reinforced Concrete. By M. Vais, Wiesbaden: the roof of St. Martin's Church, Ebingen (Würtemberg), consisting of two intersecting barrel vaults, has been constructed in reinforced concrete.—*Deut. Bauzt.*, 25.4.06.

Reinforced Concrete Filter Bed Roofs, Indianapolis: giving general design and methods of construction of the slab and girder roofs built from the designs of Mr. Theo. L. Condron, for two of the open filter beds of the Indianapolis Water Company.—*Eng. News*, 26.4.06.

Seine Tunnel of the Paris Metropolitan Railway: the Clignancourt-Porte d'Orleans line of the Paris Metropolitan passes under the Seine. An iron tunnel constructed by the shield method has been adopted and is described, together with an alternative design in reinforced concrete, which was proposed but not adopted. —*Beton u. Eisen, Apr. and May*, '06.

Promenade Hall at Johannisbad [Bohemia]. By Hr. Janesch: a description, with detailed drawings of a light and graceful structure in reinforced concrete.—*Beton u. Eisen, May*, '06.

High-Level Water Reservoir at Nuremberg. By C. Weber: this reservoir is constructed of concrete composed of lime, sand, stone and Rhenish trass, with the addition of some cement to hasten the setting. The inner surface is finished with cement and sand, without trass. —*Beton u. Eisen, May*, '06.

Printing Works at Augsburg: a factory of reinforced concrete.—*Zement u. Beton*, 1.5.06.

Siphon over the Sosa, near Monzon (Spain). By Dr. F. von Emperger: this siphon, forming part of a large aqueduct, crosses the Sosa Valley, and consists of two reinforced concrete tubes, 1,018 metres long, carried on concrete arches.—*Beton u. Eisen, May*, '06.

Difficult Reinforced Concrete Retaining Wall Construction on the Great Northern Railway (U.S.A.): full account of difficulties experienced in building a retaining wall on the Rocky Mountains on a very steep and treacherous hillside, composed of very unstable materials resting on a stratified formation of soapstone that dips at an angle of about 45 deg. A reinforced concrete retaining wall 21 ft. high and 240 ft. long has been successfully built, which it is believed will prove of ample strength and stability to meet the unusually severe conditions imposed.—*Eng. News*, 3.5.06.

The Rational Proportioning of Structures in Ferro-Concrete: an objection commonly raised by engineers and architects to the use of ferro-concrete is that they are obliged to put themselves in the hands of certain patentees, and that no data are available by which the adequacy of the proposed proportions can be verified. With the object of obviating this objection to some extent, the Armoured Concrete Constructions Company have drawn up a note concerning methods of checking the dimensions proposed for armoured concrete on the Coignet system, the same methods being said to be also applicable to any other rational system of reinforced concrete construction.—*Engineering*, 4.5.06.

Typical Systems of Reinforced Concrete Construction: Describing and *ill.* various types of reinforced concrete design in a manner convenient for comparison. —*Scient. Am.*, 12.5.06.

Reinforced Concrete Enclosing Walls. Preparation of Concrete Walls: Descriptions of portable apparatus to replace the ordinary wooden centering in the erection of enclosing walls, etc.—*Zement u. Beton*, 15.5.06.

New Custom-House and Bonded Stores at Wurzburg. By Dipl.-Ing. Luft, Nuremberg: this large building of four floors and basement, is entirely constructed in reinforced concrete. The basement floor is 3 metres below the level of the River Main, giving rise to special difficulties of construction.—*Deut. Bauzt., May* 23, '06.

Determination of the Reinforcement in Rectangular Sections. By R. Saliger.—*Deut. Bauzt., May* 23, '06.

Papers.

The Economical Design of Reinforced Concrete Floor Systems for Fire-resisting Structures: By Mr. John S. Sewell: was reported in the Proceedings of the American Society of Civil Engineers for December last, and in the Proceedings for March and April will be found a lengthy discussion, *ill.* with numerous designs. —*Proc. Am. Soc. C.E., Mar. and Apr.*, '06.

Ferro-Concrete: a paper read at a combined meeting of the Architectural Association and the Junior Institution of Engineers by Mr. Sven Bylander, and report of discussion thereon.—*Bldr.*, 21.4.06, and 19.5.06.

III.—STEEL CONSTRUCTION.

Article.

Structural Steelwork in a New York Office Building: containing particulars of the steel-cage for a new fourteen-story office building in New York. This is one of the largest structures of its kind in that city rising to the height of about 350 ft., and covering an area of 192 ft. by 75 ft. *Ill.*—*Eng. Rec.*, 14.4.06.

IV.—MATERIALS, TESTS, AND FORMULÆ.

Articles.

Comparison Between Concrete Decking with and without Reinforcement. By R. Stölcker and Prof. Ramisch.—*Zement u. Beton*, 1.4.06.

Government Tests of Structural Materials: in a report by the Director of the United States Geological Survey, it is stated that the investigations now pending include the following: (1) Examination as to the nature and extent of deposits suitable for building and construction purposes; (2) the testing of building materials collected by the survey experts in different parts of the country; (3) the testing of cement mortars made with different grades of sand, gravel, and stone screenings.: (4) the influence of time, temperature, and other variable conditions upon the setting, strength, porosity, permeability, and other properties of cements and cement mortars; (5) the testing of concretes made with stone, gravel, sand, cinders, and slags, collected from different parts of the country; as to their strength, permeability, action under freezing, fire, and other properties which concern the adaptability of these concretes for use as building material.—*Eng. News*, 5.4.06.

Influence of Changes in the Thickness of the Plate on the Stresses in Reinforced Concrete T-Beams. By E. Turley, Düsseldorf.—*Zement u. Beton*, 15.4.06.

Experiments with Reinforced Concrete T-Beams. By Prof. Max Moller, Brunswick.—*Deut. Bauzt.*, 25.4.06.

Testing of Earthenware and Cement Pipes (continued): methods of testing the power of pipes to resist internal pressure and penetration of water.—*Beton u. Eisen, Apr. and May*, '06.

Experiments with Reinforced Concrete. By M. Marcichowski: a description of bending and compressive experiments performed at the Technical High School of Lemberg.—*Beton u. Eisen, May*, '06.

Continuous Beams and Statistically Indeterminate Systems in Reinforced Concrete Construction. By G. Kaufmann.—*Beton u. Eisen, May* '06.

Considere's Rules in the Light of Kleinlogel's Experiments. By A. Kleinlogel and A. Ostenfeld: a controversy.—*Beton u. Eisen, May*, '06.

Calculation of Eccentrically Loaded Reinforced Concrete Columns. By Prof. F. Ramisch, Breslau.—*Zement u. Beton*, 1.5.06.

Calculation of Reinforced Concrete Panels Fixed at the Edges. By Prof. G. Ramisch, Breslau.—*Zement u. Beton*, 15.5.06.

V.—SPECIAL SUBJECTS (BRIDGES).

Articles.

Reinforced Concrete Viaduct (at Gisors).—*Le Ciment, Mar., '06.*

Bridge at Rouillon: in the construction of this bridge over the Meuse, reinforced concrete caissons were employed. The structure is entirely in reinforced concrete.—*Le Beton Armé, Mar., '06.*

Arch Rib Bridge of Reinforced Concrete at Grand Rapids, Mich. By G. J. Davis, Instructor in Civil Engineering, Wisconsin University; the bridge described is of a type unusual in the United States and forms an approach to the steel truss bridge across Grand River. The arch, of 75 ft. span, crosses an old channel which was to have been filled on completion of the steel bridge, but a disastrous flood in 1904 convinced the authorities that it would be inadvisable to restrict the waterway. A short span truss next to the 324 ft. draw span of the steel bridge would have been inharmonious, so the reinforced concrete arch was decided upon. Among the advantages of the design are the lightness of the arch, which reduces the thrust on the end pier of the truss bridge; the facility in time of flood for water to pass through the open spandrels; and the general harmony between the steel bridge and the concrete arch owing to the light appearance of the posts and ribs. The concrete used in the bridge was made in the proportions of 1 to 7 for the abutments, and 1 to 5 for the remainder of the structure. Mixing was performed in a cubicle machine operated by electricity. With the exception of a small amount in the stiffening webs and wing walls, all the reinforcement in the bridge and its abutments was of high-carbon steel deformed rods of ½ in., ⅝ in, and ⅞ in. sizes, splices being made by overlaps equal to thirty diameters in length. The bridge was designed to carry 15-ton road roller, or a 24-ton electric car, or a uniform load of 250 lb. per square foot in the roadway and 100 lb. per square foot on the side walks, the factor of safety being four for live loads.—*Eng. News, 22.3.06.*

Reinforced Concrete Arch Bridge at Peru, Indiana. By Daniel B. Luton, President of the National Bridge Company, Indianapolis: one of the longest reinforced concrete bridges ever built was completed in December, 1905, across the Wabash River at Peru, Indiana. The bridge is remarkable for the short time occupied in construction, the actual period covered having been less than seven months. Some novel features were introduced in the balancing of the thrusts of unequal spans on extremely light piers. The total length of the bridge is 700 ft., with 30 ft. roadway about 30 ft. above low water. There are seven arches of 75, 85, 95, 100, 95, 85, and 75 ft. span respectively, supported on piers having thickness of only 6 ft. at the springing and 8 ft. at the base. The completed structure contains about 5,000 cubic yards of 5 to 1 gravel concrete; the earth filling weighs over 10,000 tons, and the superstructure above springing weighs about 16,000 tons with its loading. The reinforcement of the arch rings was executed in accordance with the Luten system of single rods extending along the intrados at the crown and along the extrados at the haunches, and crossing the arch ring at points approximately bisecting and trisecting the half-ring. The reinforcement consists wholly of ¾ in. smooth steel rods with the elastic limit of about 40,000 lb. per sq. in. spaced 12 in. apart in the arch ring, and constituting less than 2-10ths of 1 per cent. of the crown section. The total cost of the bridge was about £7,400, of which amount the reinforcement represented £1,125 or about 15 per cent.—*Eng. News, 29.3.06.*

Bridge at Buchelsdorf, near Freiwaldau. By R. Deifel: the bridge over the Biela at Buchelsdorf, in Silesia, having been destroyed by a flood, has been replaced by one in reinforced concrete of 19·5 metres span. —*Beton u. Eisen, Apr., '06.*

Ferro-Concrete Bridge at Colne: constructed on the Hennebique system in connection with the Bridge Street and Knott's Lane improvement at Colne. The arch has a span of 45 ft. 6 in., with a rise of 5 ft., the thickness of the rib being 14 in. at the springing and 10 in. at the crown.—*Bldg. News, 13.4.06.*

New Reinforced Concrete Bridges, Constructed by E. Zublin and Co., Strassburg, B.H., Schurch: detailed drawings and stress of bridges at Moulins and Montigny, near Metz, and over the Orne at Rombach.—*Beton u. Eisen, May, '06.*

SOME SUBJECTS DEALT WITH IN No. 2.

Reinforced Concrete in the United States	Capt. Sewell, U.S.A
Reinforced Concrete Piles in Tidal Waters	A. T. Walmisley, M.Inst.C.E.
Reinforced Concrete on the G.W.R.	W. Armstrong, M.Inst.C.E.
Hollow Concrete Block Building	S. B. Newberry, Cleveland, U.S.A.

The R.I.B.A. and Reinforced Concrete—Fictitious Portland Cement—The Merchandise Act—Reinforced Concrete Roofs in Egypt—A Reinforced Concrete Bridge at Indiana, U.S.A.—Water Tower at Bournemouth—Flow of Concrete under Pressure—Fire Tests with Reinforced Concrete—Loose Stirrups *versus* Rigid Shear Members in Reinforced Concrete Beams.

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IMPORTANT ARTICLES.

The following, among others, are kindly contributing Articles:—

W. H. HUNTER, M.Inst.C.E., Chief Engineer, Manchester Ship Canal.

CHARLES F. MARSH, M.Inst.C.E., M.Inst.M.E., Author of "Reinforced Concrete."

EDWIN O. SACHS, F.R.S.Ed., Architect.

Captain SEWELL, Corps of Engineers, United States Army.

JAMES SHEPPARD, Surveyor, North British and Mercantile Insurance Company.

W. NOBLE TWELVETREES, M.Inst.M.E., Author of "Concrete-Steel."

A. T. WALMISLEY, M.Inst.C.E., Engineer, Dover Harbour Board.

Lieut.-Colonel J. WINN, R.E., Author of "Notes on Steel-Concrete."

R. H. WYRILL, M.Inst.C.E., Waterworks Engineer, Swansea.

The following, among others, are kindly presenting occasional contributions on the Setting of Portland Cement:—

H. K. G. BAMBER, F.C.S.

D. B. BUTLER, A.M.Inst.C.E., F.C.S.

Dr. W. MICHAELIS (Berlin).

CECIL H. DESCH, D.Sc., Ph.D.

H. HOWARD HUMPHREYS, M.Inst.M.E.

N. DE TEDESCO (Paris).

RICHARD L. HUMPHREY, M.Am.Soc.C.E. (Philadelphia).

SOME SUBJECTS DEALT WITH IN No. I.

The Advent of the Concrete Age..	LIEUT.-COL. E. A. WINN, R.E.
Steel Skeleton Construction and the London Building Acts..	W. NOBLE TWELVETREES, M.Inst. M.E.
Reinforced Concrete Construction	CHARLES F. MARSH, M.Inst.C.E.
The Setting of Portland Cement..	CECIL H. DESCH, D.Sc.
The Preservation of Iron and Steel	B. H. THWAITE, C.E.
Reinforced Concrete at Munich (The New "Tietz" Stores) .	

Impending Conferences on Reinforced Concrete—The Fire Resistance of Concrete—Fictitious Portland Cement—Safeguards against Freezing in Concrete Construction—Concrete Railway Sleepers in U.S.A.—New York Rules on Reinforced Concrete—German Portland Cement Manufacturers—A Reinforced Concrete System with Rigid Shear Members

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CONCRETE
AND
CONSTRUCTIONAL ENGINEERING

Volume I. No. 4. SEPTEMBER, 1906.

EDITORIAL NOTES.

INTERNATIONAL STANDARDS FOR REINFORCED CONCRETE.

WE have much pleasure in announcing that at the impending meeting of the International Association for Testing Materials a resolution will be proposed advocating the formation of a special commission to be entrusted with the investigation and standardisation of matters appertaining to reinforced concrete.

Practically the whole of the members of the Association, who are scientifically and technically interested in reinforced concrete, are unanimous as to the necessity of the subject being taken up independently and on international lines. It would thus appear almost certain that a special commission on the subject will be formed during the early days of September and it may be anticipated that with the usual thoroughness of the Association, the commission's work will be divided up among a number of sub-committees, upon which we trust Great Britain will be duly represented.

THE CONGRESS OF ARCHITECTS.

THE Seventh Architects' Congress has come and gone, and although there was much that was instructive, and the Congress was socially a great success, we had certainly expected to learn more in respect of constructional engineering and reinforced concrete in particular. Steel skeleton construction, although on the programme, was entirely ignored, and reinforced concrete only had attention on points of detail. We are dealing with the Congress elsewhere, but would take the opportunity of pointing to the special report we have prepared of the meeting on reinforced concrete, facilities for recording which were kindly accorded by the indefatigable Congress Secretary, Mr. W. J. Locke, M.A.

FAILURES IN REINFORCED CONCRETE.

ONE of the most valuable resolutions of the recent International Congress of Architects dealt with in this issue was one at the instance of Mr. Max Clarke, F.R.I.B.A., as to the necessity of inquiry into the causes of failure in reinforced concrete. We trust that when the International Association for Testing Materials takes up the question of reinforced concrete this resolution may be brought to their notice, and an effort made to systematically collect the necessary data.

We know of no society that could more suitably and easily undertake such work than the International Association. Nothing could be of greater value to the development of reinforced concrete in modern constructional work than a clear—impartial—discussion as to the causes of failure and the conditions under which they have occurred, so that repetitions may be avoided and any lessons obtainable immediately taken to heart.

It would be unwise for the enthusiast not to accord proper attention to any instance of failure that may have occurred with reinforced concrete as with all other structural materials, for it is from the lessons of such instances that so much can be learnt.

REINFORCED CONCRETE AS A FIRE RESISTANT.

We would call attention to the resolution passed at the recent Congress of Architects to the effect that where reinforced concrete is intended to be fire-resisting, the greatest possible care must be taken in the selection of the aggregate, its size, and in the protection of the steel. On referring to our previous number, it will be found that an almost identical resolution was arrived at during the International Fire Service Congress at Milan, where, however,some of the necessary precautionary measures, such as maximum size of the aggregate and the minimum thickness of the covering were specified in detail.

The resolutions read together and emanating from two important meetings, both interested in the safety of buildings from fire, should certainly have the attention of our public authorites and they should be valuable to all concerned as laying down the principle that, although reinforced concrete comprises incombustible materials, reinforced concrete cannot be looked upon as fire-resisting unless certain safeguards be applied as to the covering of the steel, and the selection of the aggregate. The sooner this is fully realised the better, for the true development of reinforced concrete in buildings intended for industrial purposes.

CONSTRUCTIONAL WORK AT SAN FRANCISCO.

In our current issue we are presenting a most important article by Captain Sewell, of the United States Military Engineers, embodying his views as to the value of reinforced concrete as a fire resistant, in conjunction with some observations generally as to the effect of earthquake and fire upon constructional work in San Francisco. In the article in question, the gallant officer—whose practical experience in the execution of public buildings is almost unprecedented—holds the balance fairly even as between reinforced concrete and porous terra-cotta in its best sense as distinct from the dense commercial commodity so recklessly put upon the market in certain parts of Europe as well as in the States. The able author, however, seems to almost favour a combination of reinforced concrete with porous terra-cotta, a combination which he has adopted in some of his recent works, as will be seen from our second issue.

Captain Sewell's article requires the most careful perusal, being most nicely argued, and in presenting such an article we are proud to again be able to give some indication of the fact that we are desirous of publishing the views of the leading independent authorities of the world on matters appertaining to Concrete and Constructional Engineering generally, no matter whether we agree or disagree with the conclusions arrived at by any one individual author. Our own views —already previously expressed—are to the effect that reinforced concrete has made a most excellent showing both in respect to shock and fire resistance on the occasion of the great catastrophe at San Francisco, but we regret that the examples were not more numerous for the purposes of inquiry, and that the data must necessarily be incomplete.

A reliable contribution, however, such as this of Captain Sewell's, must be of the utmost importance to those who employ and desire to appreciate the relative values of building materials and systems of construction, but we should perhaps again warn our readers against the unreliability of much of the literature, the *ex parte* addresses and catalogues that are finding their way from the United States into this country in connection with the San Francisco disaster, in comparison with which Captain Sewell's writings are such splendid exceptions.

LITIGATION AS TO REINFORCED CONCRETE.

WE regret to observe that matters appertaining to the use of reinforced concrete have recently become the subject of several law-suits. Mr. Mouchel, representing Messrs. Hennebique, being the plaintiff in two notable cases *versus* Messrs. Coignet and others, and *versus* Messrs. Cubitt respectively.

Although reinforced concrete or its equivalent was occasionally employed in this country quite fifty years back, the more modern systems or methods of application are essentially of Continental or American origin, and comprise features or details deservedly the subject of patents both at home and abroad. The law of Great Britain as to patents and the anticipation of patents in particular, is, however, most complex, and we thus find legal controversies arising and findings which, however good in law, do little credit to commonsense.

One thing, however, is certain, and that is that contractors alike should be warned against the *ex parte* statements of specialists, as to patent rights and the extent of any judicial findings, and should inform themselves by the aid of independent sources of the general position of reinforced concrete patents, before embarking upon new works or taking out licenses.

As to the question of licenses in particular, we hold that the contractor should also always have most careful technical and legal advice, otherwise he may find his hands tied in a manner he least expects.

Having regard to the importance of the patent question and the methods of licensing, we propose arranging for some special articles on the subject, and would immediately refer those who are interested in concrete blocks, to an article of ours in the preceding issue.

We shall also organise a department to assist inquirers with advice as to technical points, and we are already prepared to welcome inquiries.

THE STANDARDS COMMITTEE ON CEMENT.

As intimated in our previous issue, the Committee on Cement constituted by the Engineering Standards Committee is again holding meetings with the view of improving the existing standard specifications. Our remarks as to the necessity of reducing the influence of the personal element as a factor in cement tests appears to find favour amongst those primarily concerned, but the difficulty is to find suitable mechanical contrivances to supersede manual manipulation.

We also observe that there is considerable feeling that metric equivalents should be published in respect to all weights and measures in the specification, and having regard to the international importance of these standards and the efforts that should be made to assimilate our practice to the requirements of foreign markets, we should certainly favour this, pending the issue of the standards solely with figures on the metric system.

CONCRETE EXPOSED TO SEA-WATER.

IN the course of a paper dealing with the design of "Commercial Dry Docks," Mr. J. Mitchell Moncrieff, M.Inst.C.E., of Newcastle-on-Tyne, makes some remarks based upon an extended use of concrete in structures exposed to the action of sea-water. The author points out that the cheapness of concrete as compared with masonry, the facility it affords for the execution of work without the necessity for adopting regular courses, and the assumed monolithic character of work consisting of batches deposited one upon another, have been looked upon as special recommendations of the material in many marine works. Some of these supposed virtues, he adds, have now been shown to be vices, particularly in the construction of dry docks. Mr. Moncrieff evidently does not mean to suggest that the cheapness of concrete constitutes a disadvantage, but rather that the attempt to secure economy has led many engineers to adopt proportions which, although quite suitable for ordinary use, are totally unsuitable for structures exposed to sea-water. Experience during the last twenty years shows that the action of the sea-water upon Portland cement causes gradual swelling of the mortar and consequent disintegration of the concrete. The extent to which these effects follow, and the rapidity with which they develop, are in direct proportion to the permeability of the concrete. Hence it is of the utmost importance that the concrete should be proportioned so as to prevent inward percolation of sea-water into or through the material. To this we may add that if the concrete be made as it should be, and with Portland cement obtained from first-class and experienced makers, there should be no reason for fearing disintegration. But concrete dock work should not be executed in the haphazard manner usually permitted in the past. The author has known water to travel through an apparently solid concrete wall for a distance of between 30 ft. and 40 ft. along irregular seams, the very irregularity of which made it almost impossible to take steps for preventing the permanent percolation of water through the mass of concrete. Therefore he advises that all concrete work in dry dock construction should be carried out on regular horizontal and vertical lines; the beds should be quite flat and level, and before a fresh batch of concrete is deposited upon the surface of partially set material, all loose stone and weak stuff should be removed and a layer of mortar put upon it. To neglect such precautions is to court ultimate disaster, however carefully the concrete itself may have been made. Perhaps the most important point in connection with concrete for dry-dock construction is that mixtures which would be quite good enough for most land structures are certain to prove unsatisfactory under the continued action of sea-water. Dry docks require the ratio of cement to aggregate to be a high one.

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Reinforced Concrete AS A Fire Resistant.

Some Notes on Constructional Lessons from San Francisco.

By CAPTAIN SEWELL,
Corps of Engineers, United States Army.

In concluding his observations upon the development of Reinforced Concrete in the United States for an article appearing in our second issue of May last, Captain Sewell commented upon matters relating to fire resistance. Between the time of writing those observations and their intended publication, the catastrophe at San Francisco had taken place, and the issue of those observations was deferred until additional particulars could be obtained as to the constructional lessons to be learnt from San Francisco.

The following article comprises the observations deferred, together with the author's comments on the lessons named, and they should prove highly instructive reading, particularly as they are supplemented with illustrations reproduced from photographs so carefully taken for the author on the spot.—ED.

STEEL is not fireproof, though incombustible under ordinary conditions. Concrete is not thoroughly fireproof, but its resistance to fire is very great. Upon this property of concrete, combined with the fact that it is a poor conductor of heat, depends the value of reinforced concrete in fire-resisting structures.

Laboratory tests indicate, quite clearly, that Portland cement which has set begins to lose its water of crystallisation at temperature about 600 deg. to 800 deg. F. This change takes place in an actual concrete structure subject to fire, at a rate depending upon the temperature and duration of the fire, and also upon the progress of the change itself. When the water is all driven off, the concrete is ruined. But the process of dehydration is slow, and consumes much of the energy of the fire, the dehydrated material at the surface generally remains in place, and acts as an insulating covering for the sound material behind it. An ordinary fire would probably exhaust itself, or be brought under control, in most cases, before fatal damage would result from dehydration alone to a well-designed structure. But in addition to the dehydration there are other injurious effects, due to expansion and contraction of considerable areas, or large units of the structure, if the fire is long continued; probably even more serious damage often results from strictly local effects of the same sort, even where dehydration has not progressed to a fatal degree. To these latter injuries, reinforced concrete is subject, in common with all other types of fire resisting construction—brickwork included.

Experience with fires and fire tests in the United States indicates quite clearly that the chief enemy of fire-resisting structures is not so much molecular changes, such as the dehydration of cement, as the stresses due to expansion and contraction, under which all materials spall, more or less. It follows from this that as far as possible, structural duty and resistance to fire should be differentiated. The same material should not, in an ideal design, be expected to perform both duties. In practice this is not usually possible of attainment ; but in reinforced concrete members a sufficient thickness of material, over and above that required for structural duty alone, should be added on all exposed surfaces, to enable the members to suffer what is generally the maximum loss by dehydration and spalling, without diminishing their structural value.

Some reinforced columns recently built in New York were cast in place, inside of forms consisting of drums of cinder concrete, reinforced with expanded metal. The structural concrete on the inside was of broken stone. This arrangement was almost ideal, so far as the columns are concerned. The cinder concrete drums could not take much of the structural stress from the column proper. Their only function is to serve first as a form and afterwards as a fire-resisting covering, for the structural covering inside. Damage to the drums as a result of fire could be easily repaired. Fire damage to the main column is practically impossible.

While thoroughly satisfactory fire tests have not been made in the United States, even in the Baltimore conflagration, enough has resulted from what has been done to demonstrate that reinforced concrete in itself is quite a satisfactory material for all ordinary fire-resisting structures ; while not as efficient for fire-resisting purposes as burned clay in its most efficient forms and methods of application, it is better than most commercial forms in which burned clay is applied. It would not be surprising, however, if the future tendency in the more important buildings should be to treat reinforced concrete as a structural material, pure and simple, and to protect it much as steel work is now protected.

REINFORCED CONCRETE AT SAN FRANCISCO.

Since the preceding words of this article were written, the San Francisco earthquake and its resulting conflagration have occurred. The writer visited the ruins shortly after the catastrophe, with a view of learning the effects of fire and earthquake on structures in general, and on modern buildings in particular.

There was very little reinforced concrete construction pure and simple in the affected district. At Palo Alto, at the Leland Stanford University, there was a museum building which consisted of three wings ; the central one of reinforced concrete, and the two side wings of brickwork, with reinforced concrete floor systems. This building was not far from the line of the fault which caused the earthquake, and it received a very severe shaking. Externally, the reinforced concrete wing appeared to be absolutely uninjured, except that some statues were shaken down from the front parapet wall. The two brick wings were in practically a state of collapse. An examination of the interior showed that some damage had been done in the reinforced concrete building, in the shape of a few cracks here and there ; but the sum total of structural damage was insignificant, and the writer is inclined to think that one thousand dollars would cover all the damage to this wing. The damage to the brick wings is at least from 50 per cent. to 75 per cent.

There was also a building used for a girls' dormitory at Stanford University, which had reinforced concrete walls, with ordinary timber floor construction ; the only damage done to this building was due to a heavy chimney toppling over and coming down through the roof. Very good photographs of the damage to the various buildings at Stanford University are to be found in the current numbers of *Engineering News* and *Engineering Record*.

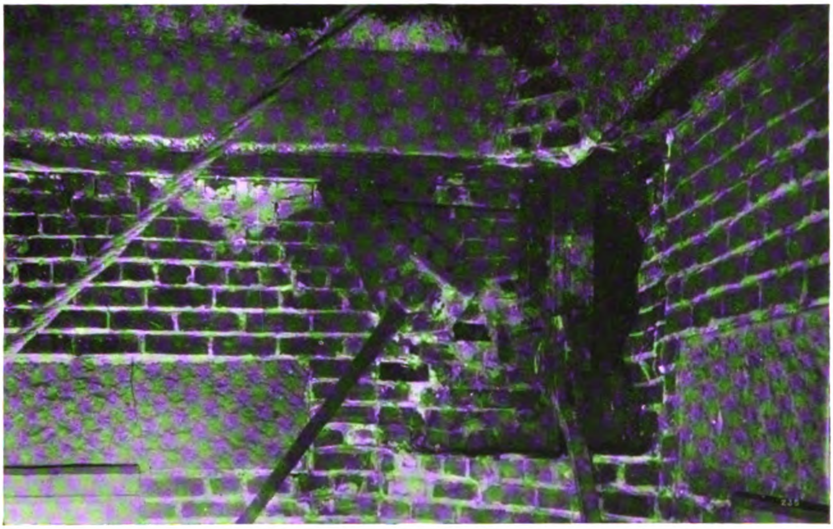


FIG. 1. A DIAGONAL BRACE IN THE "FERRY" BUILDING, SAN FRANCISCO.

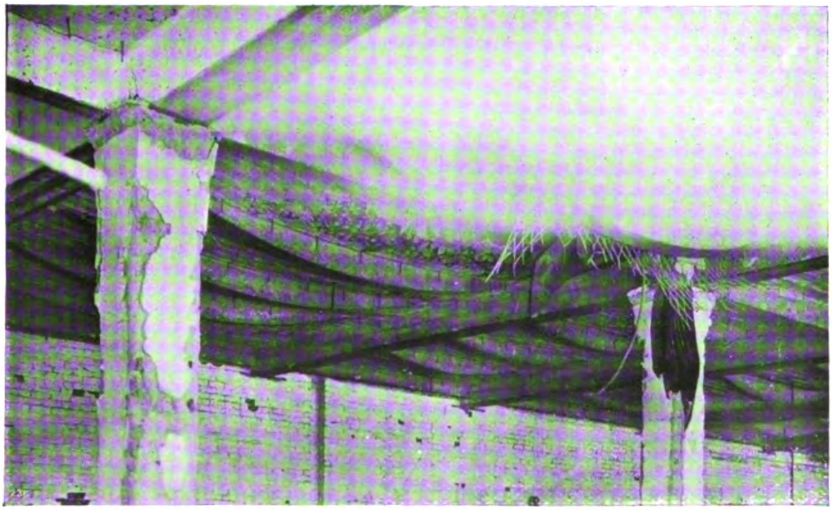


FIG. 2. PORTION OF A REINFORCED CONCRETE FLOOR, SAN FRANCISCO.

The Post Office building at Palo Alto was also a reinforced concrete structure, and it was said to be absolutely undamaged. Damage to other types of buildings at Palo Alto was very general, and quite severe. The writer saw a number of tall eucalyptus trees at Palo Alto, which had been shaken down by the earthquake; a phenomenon not noticed by him elsewhere. It would seem justifiable to conclude that the reinforced concrete structures at Palo Alto had a very severe test, and one which was a fair basis of comparison with brick and stone structures. The reinforced concrete undoubtedly proved its superiority to both of the other materials, even when they were very well laid. None of the buildings at Palo Alto were very tall, and none of them were subjected to fire.

In San Francisco proper there was practically not a single reinforced concrete building, but there were a great many buildings in which reinforced concrete floor slabs were used on steel beams, and there were a few in which the entire floor system was of reinforced concrete. One of the latter was the Academy of Sciences, in Market Street, of which a good view appears in *Engineering News* of June 7th, 1906, at page 623. This building had thin cast-iron columns filled with concrete, carrying reinforced concrete floors, consisting of beams and slabs reinforced according to the " Ransome System." The floor construction was built by Mr. Ransome about the year 1890, or shortly thereafter. The reinforced concrete was absolutely undamaged by the earthquake, but considerable spalling occurred in the fire, which burned out everything combustible in the building. The behaviour of reinforced concrete in the San Francisco fire confirmed in every respect the description of its properties as exhibited under such circumstances, as set forth in the preceding part of this article.

It was a very common practice in San Francisco, where reinforced concrete slabs were used, to have also a furred ceiling attached to the lower flanges of the floor beams. Where this ceiling was well put in, it resisted the fire for quite a time, and protected the concrete from the direct impact of the flames until the energy of the fire was more or less expended. Under such circumstances, the floor slabs were comparatively little damaged. At other points, where they received the direct impact of the flames for an appreciable time, it was evident that the damage was quite serious. The cement had lost its water of crystallisation and the concrete was dead and friable to a considerable depth from its surface. The floor slabs did not always show a deflection under these circumstances, however, because the fire had operated to relieve them of the load, and they had nothing to carry but their own weight; so that, although there was no doubt whatever that their strength was seriously impaired, they stood up and presented a very fair appearance; no doubt the average layman would think they had come through quite successfully.

SOME EXAMPLES FROM SAN FRANCISCO.

There are submitted herewith a number of photographs which may be of interest in connection with the fire and earthquake.

Fig. 1 is a view taken in the interior of the tower of the large Ferry Building. This tower had a steel frame clothed with a brick wall, faced with sandstone. It was subjected to a severe shaking by the earthquake, and in the view will be

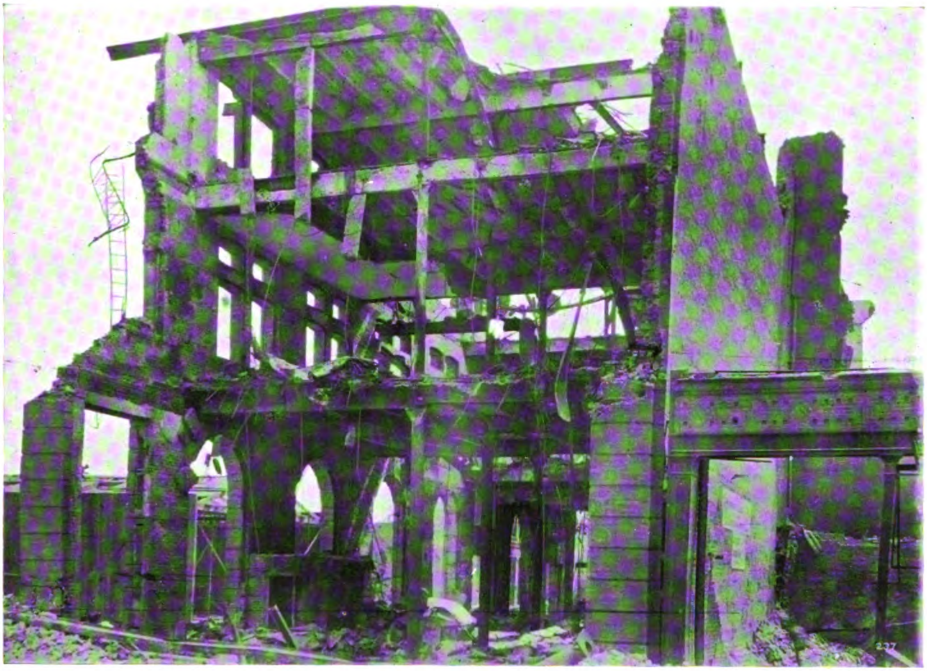


FIG. 3. RUINS OF A BUILDING AT SAN FRANCISCO.

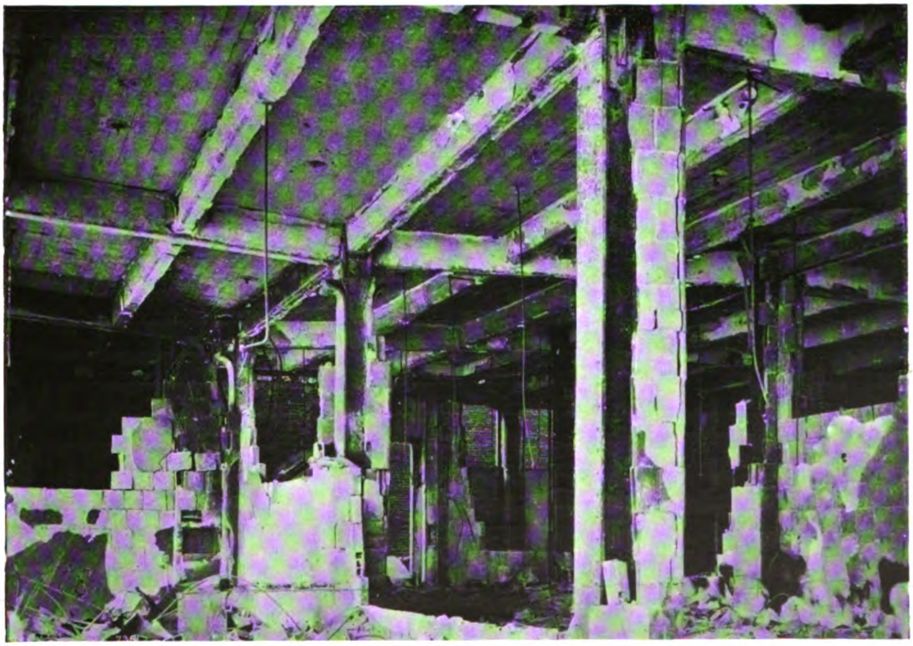


FIG. 4. TERRA-COTTA AT THE "ARONSON" BUILDING, SAN FRANCISCO.

seen one of the diagonal braces, which had been fastened to the lower flange of the combined wall girder and wind strut by means of a gusset plate and angle iron. The rivets fastening the gusset plate to the angle iron were all sheared but one, and the view shows the end of the tie rod hanging on the gusset plate, and this hanging in turn by one rivet. The twisted cables which appear in the view had been put in to hold the framework together during the process of demolishing the masonry, which was under way when the writer saw it.

In view *Fig.* 2 is shown a portion of a reinforced concrete floor system carried on steel columns and girders. The building in which this occurred was not subjected in general to a fierce heat ; but a lot of packing material happened to be stored on the floor immediately under the point where the damage shown in the photograph occurred. On top of the floor above was a pile of sheet iron. It will be observed that the concrete flaked off under the heat, exposing the expanded metal reinforcement. This got hot and finally the pile of sheet iron was on the point of coming through ; some of the sheets can be seen hanging down immediately on the right hand of the photograph. There is at least this to be said in favour of the reinforced concrete, however ; if a hollow tile floor had begun to collapse to the extent indicated in the photograph of the reinforced concrete floor, the collapse would probably have continued and the load would have fallen through, and by its impact would probably have gone on through every other floor to the basement. The concrete in the floor construction of the building shown in *Fig.* 2 was cinder concrete, and examination on the spot showed very clearly that it had been very seriously damaged by the fire even in places where no considerable deflection had occurred.

In *Fig.* 3 is shown the ruins of a building which had naked cast-iron columns, steel girders, reinforced concrete beams from girder to girder, and reinforced concrete slabs from beam to beam. The beams were reinforced with single round rods, which were put through holes in the webs of the steel girders, and were there secured by nuts in the same manner as tie rods. There was a suspended ceiling in this building, but the fire brought it down almost entirely. The remains of the collapsed ceiling can be seen at the edge of the second floor and on top of the brick vault on the first floor. To the right, in the second story, the floor construction of the story above is seen to be very seriously deflected ; this was manifestly due to the damage resulting from the fire. The heat in this building could not have been very severe, otherwise the naked cast-iron columns must have collapsed ; yet the greater part of the ceiling came down and the fire still had energy enough to practically ruin the reinforced concrete. The concrete in this building seemed to be made of a mixture of broken stone and cinders, but it was impossible to verify this beyond any doubt. The dehydration of the cement was very apparent. It was also very apparent that an insufficient amount of concrete had been provided to protect the steel reinforcement from fire, so that even the portion of the building which was standing was on the point of collapse from the heat effects on its floor system.

In photograph *Fig.* 4 is shown a view in the first story of a fire-resisting building occupied for mercantile purposes at the corner of Third and Mission Streets. It was known as the Aronson Building. As will be seen, the terra-cotta fireproofing in this building was a general failure. The floor systems were of cinder concrete. The method of reinforcement was not determined. The concrete, however, had been quite seriously damaged by the heat, notwithstanding the fact that most of the floor slabs still remained true and retained the marks of the centering used in constructing them. Two buckled columns appear in this photograph, showing the effect of heat on box columns after the fireproof covering has been destroyed by fire.

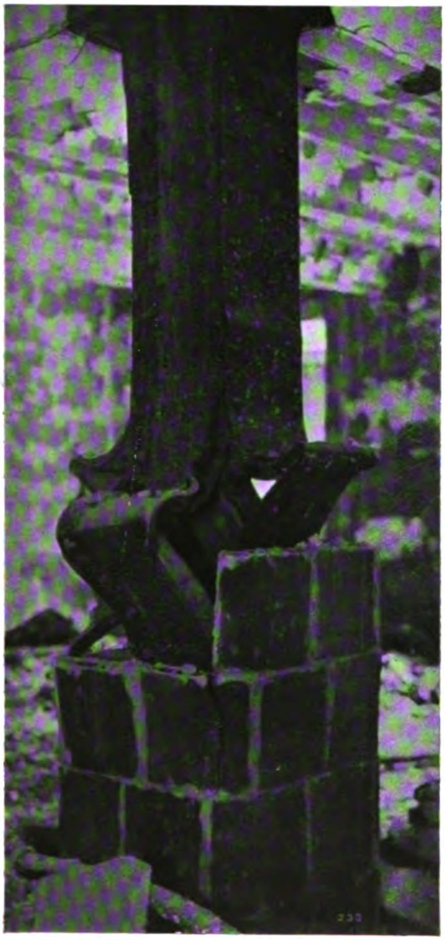


FIG. 5. TERRA COTTA COLUMN COVERING AT THE "ARONSON" BUILDING, SAN FRANCISCO.

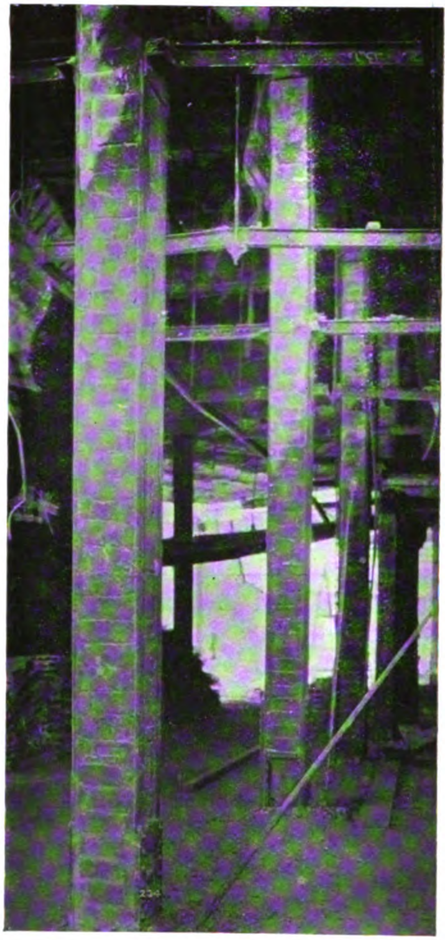


FIG. 6. SOME Z-BAR COLUMNS AT THE "JAMES FLOOD" BUILDING, SAN FRANCISCO.

Fig. 5 is a photograph of a buckled column in the basement of the Aronson Building, showing the failure of terra-cotta column covering. There were a number of columns in San Francisco covered solidly with concrete. None of these columns were in any such condition as indicated in *Figs.* 4 *and* 5; in fact, the steel had been perfectly protected, although in some cases the concrete

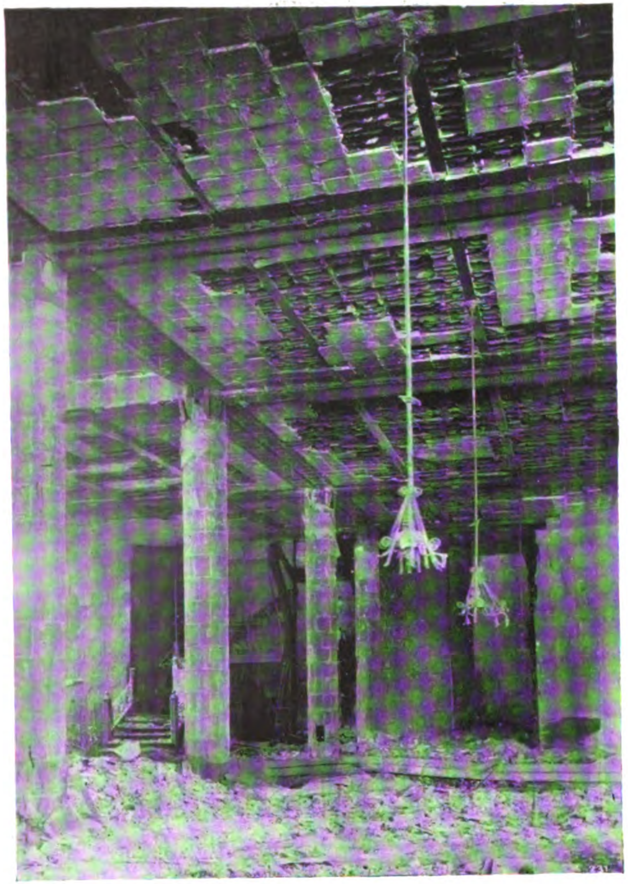


FIG. 7. PORTION OF A TERRA-COTTA FLOOR AT SAN FRANCISCO.

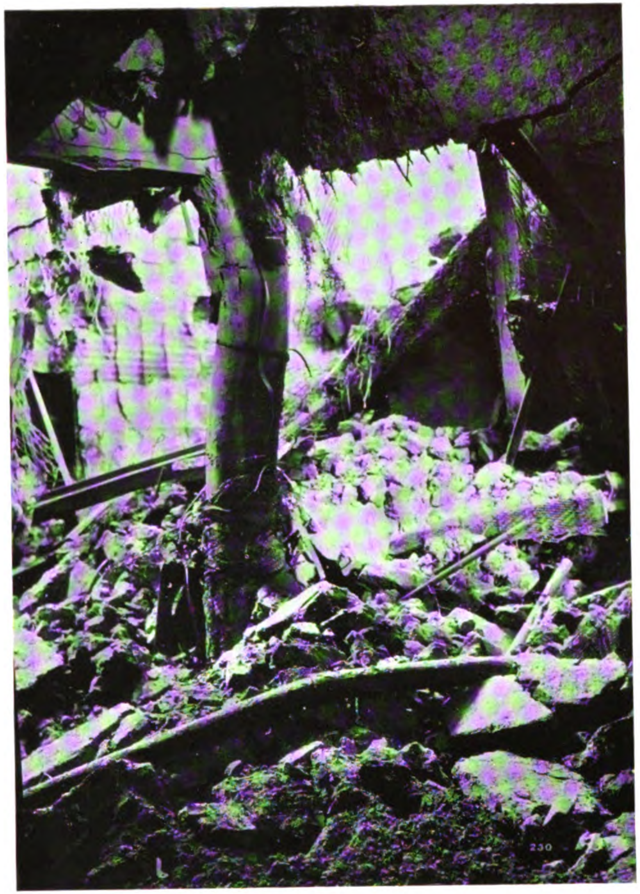


FIG. 8. SOME CAST-IRON COLUMNS PROTECTED BY PLASTER ON EXPANDED METAL LATHING.

was so badly damaged that it was itself practically a total loss. The writer observed no case, however, in which a column covered with concrete had been subjected to any such heat, as that which was evidently applied to the column shown in *Fig.* 5. This was a basement column in a comparatively small room, which had been filled very full of highly combustible matter. There was, on the outer side of the same room, a column covered with 4 in. of cinder concrete, which, on casual inspection seemed to be undamaged. More careful inspection showed, however, that the concrete had been seriously dehydrated, and that it was developing longitudinal cracks from top to bottom, which subsequent investigation proved extended quite to the column inside. There was this to be said in favour of the concrete covering, however, as compared with hollow tile; while the covering in both cases was practically a total loss, the hollow tiles allowed the column to be destroyed, whereas the concrete had saved it.

View *Fig.* 6 is of some Z-bar columns in the James Flood Building. The second and third columns from the front were slightly buckled to the right. They had been covered with hollow tiles. The fire practically took off the entire hollow tile covering, although not so completely as indicated in the photograph. At the time the photograph was taken, the tiles that remained in position had been removed and piled up to one side, as indicated in the photograph itself. It was evident, however, that these columns were on the point of failure from the heat. In the writer's judgment, the solid brick filling which appears in the photograph was the only thing that saved them.

In *Fig.* 7 is a view of a hollow tile floor, showing the characteristic damage due to the fire. Comparing this with the ceiling shown in *Fig.* 4, one would naturally conclude that the reinforced concrete construction was much better than the hollow tiles. This, however, is by no means sure. The hollow tile floor shown in *Fig.* 7 remained perfectly true, and would still carry considerable loads. It is probable that, under comparative tests, it would be developed that the hollow tile floor in *Fig.* 4, 247. still retained quite as large a percentage of its original strength as the reinforced concrete floor shown in *Fig.* 2, although the damage to the hollow tiles is very much more apparent to the casual observer. In the writer's opinion, both floors ought to be taken out and rebuilt, but if the reinforced concrete floor is allowed to remain, then it would be equally justifiable to repair the hollow tile floor by simply stretching metal lathing underneath it, and plastering the ceiling so formed.

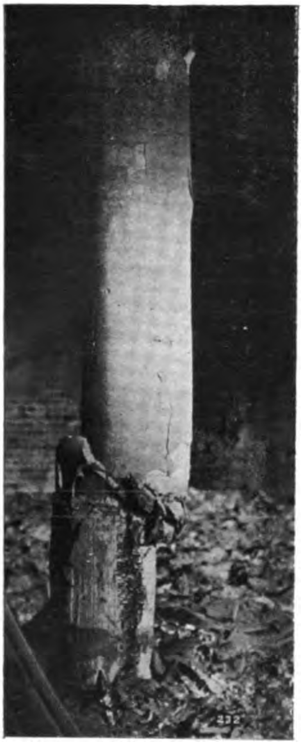


FIG. 9. A COLUMN.

In *Figs.* 8 and 9 are shown two cases of cast-iron columns which had been protected with expanded metal and plaster. They were in a basement in which a large quantity of linoleum and other highly inflammable materials were stored.

SOME CONCLUSIONS.

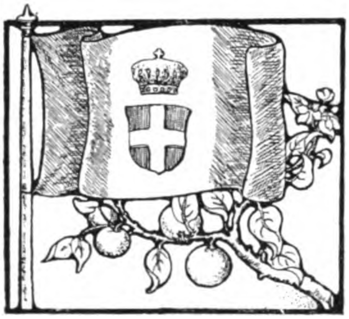
In general, the San Francisco fire brought out nothing new relative to the value of the various materials used for fire-resisting purposes. It demonstrated beyond question that in commercial work in the United States, both reinforced concrete and hollow tiles have been applied in a flimsy and inadequate way. Both the San Francisco fire and the Baltimore fire demonstrated that commercial hollow tile work was very apt to fail by expansion stresses in the exposed webs, and that reinforced concrete was likely to be seriously damaged by the dehydration of the cement. Both fires indicated clearly, however, that both of these materials can be used so as to secure adequate and satisfactory results, and, in the writer's opinion, when so used, the cost will be about the same in both cases.

While this is an article especially on reinforced concrete, the writer would point out that the serious problem in congested districts of large cities is not only the securing of a "fireproof" covering for the steel frame, or a "fireproof" construction which will have such resistance that it will come through a fierce fire undamaged, as to the devising of means of excluding an external fire.

The question of window protection is, by all odds, the most important one at the present time. Had the fire been kept out of the "fireproof" buildings in San Francisco, none of the weakness in either concrete or hollow tiles would have been developed, and even the flimsy commercial type would have been, on the whole, good enough. However, even a fire originating within would have done serious structural damage to the "fireproof" construction in San Francisco ; so that, after the question of window protection is properly attended to, the interior fire-resisting features should also be improved.

So far as the concrete itself is concerned, that which was used in San Francisco for fire-resisting purposes was so poor to begin with that the writer had great difficulty in many cases in determining whether its unsatisfactory condition at the time he examined it was due to the fire or to carelessness or neglect in its original installation. Careful examination, however, indicated that the surfaces exposed to the fire were manifestly in worse condition than the portion which had been protected from the fire, although it was all so inferior that there was not very much room for a different quality.

In order to determine the real relative efficiencies of the different types of floor construction, those of each type that had evidently been subjected to the worst heat in a place like San Francisco, ought to be tested to destruction by super-imposed loads. Of course, it is not at all probable that any such tests will be made. It seems more than probable that the better appearance of the reinforced concrete floors will cause a great many people to ascribe a fictitious value to the fire-resisting qualities of reinforced concrete ; as a matter of fact, if both the tile floors and the concrete floors were tested, as above indicated, it is more than probable that it would be discovered that all the floors of both types that had been exposed to a really severe fire test ought to be taken out and renewed, in which case the floor loss would be total for both types.



SOME REFLECTIONS
on
Reinforced Concrete and Cement Uses
after a visit to
The International Exhibition at Milan.

By FREDERIC R. FARROW, F.R.I.B.A.

The International Exhibition at Milan should be of considerable interest to engineers and architects alike, and features of some novelty will be found in the uses to which cement has been put in some of the buildings and exhibits. We herewith present an article on some of the lessons to be learnt in this direction.—ED.

THE occasion of an international exhibition of the magnitude of that now open at Milan might be expected to afford an exceptional opportunity for the study of cement uses and reinforced concrete in particular.

To some extent this expectation is not fulfilled, partly by reason of the ephemeral nature of the buildings in which the exhibits are housed, and partly from the non-spectacular value of the material in which we are particularly interested, at least as far as public estimation has as yet been led to expect.

An international, or even national, exhibition of the present day must apparently be run to a greater or lesser extent on " Earl's Court " lines, and in order that it may be possible to bring together comparative series of exhibits which will be instructive to the expert in the various branches of national or international activity, considerable regard must be paid to the public, who want amusement for their lira, their shilling, their franc, or their mark.

Hence the prominence of the model of the Simplon tunnel is but a part of the policy which has made the very fine exhibits of railway engineering, shipbuilding, and manufactures in actual work so useful a feature of the exhibition. These latter and other groups are attractive to the general public as well as of value to the expert.

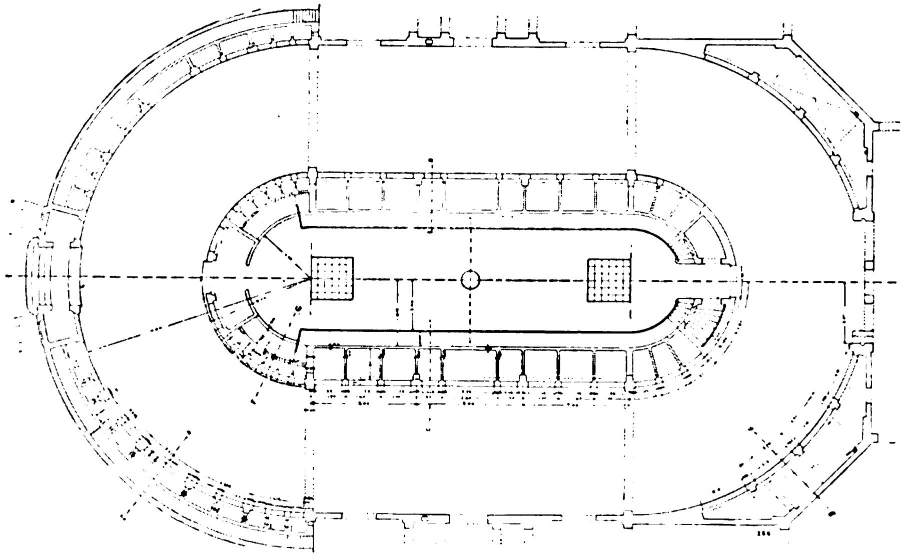
Concrete has, at least at present, less universal attraction, but the exhibition is not without interest and suggestiveness to the expert in this material.

The exhibition is housed in a large number of separate buildings that are not intended to remain in existence after the end of the present year, and are, therefore, constructed in carpentry covered with plaster, but their design is such as would be eminently suited to permanent buildings in reinforced concrete, and the typical buildings of which we give illustrations, might very well be erected in this material, and clothed in decorative form with plaster, given the practical skill of the Italian *stuccatore.*

These buildings of the Milan exhibition are, therefore, decidedly suggestive of a suitable decorative treatment for reinforced concrete construction. Nor can it be said that such treatment would be lacking in reasonable durability, for there are in Milan numerous examples of plaster treatment of façades as old as the sixteenth century. This then we would advance is one method of treatment that might be adopted by architects in their employment of reinforced concrete.

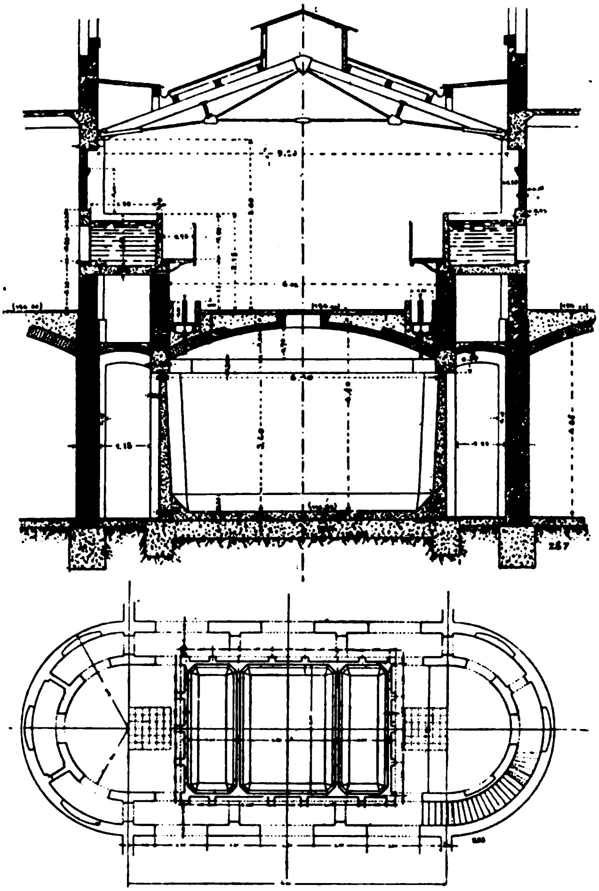
In some cases, as in the Aquarium building, which is intended as a permanent structure, the façades are finished in cement, instead of lime stucco, and here we are introduced to one of the striking features of modern Italian work in cement and concrete, the surface treatment of the material.

After the cement has set hard, the face has been worked with a chisel with an effect closely resembling that of dressed stone. In this particular building ordinary sand has been used with cement, but the modern Italian is remarkably skilful in the use of various substitutes for sand as the basis of his cement work, and by the use of them produces varied texture of surface. Marble chips are used, and brought to a polish, as in what we know as terrazza flooring. Steps, parapet walls, copings, etc., are formed of granite concrete. Columns, pilasters, and moulded work are also finished with a texture similar to that of unpolished granite, and in more than one instance, notably in that of a very fine building of sixteenth century Florentine type of detail in the Via Romagnosi, an effect resembling that of travertine has been produced by using coarse ballast and picking out some of the stones whilst the cement was wet. It may be objected by the architectural purist that these treatments of the surface are shams, but the objection is scarcely a valid one. No attempt is made by the use of false joins to imitate stone, and it is perfectly clear from the unbroken constructional planes that the material is not stone. What reason is there for carping at the artistic feeling that desires a particular surface texture, similar to that of, it may be granite, marble, sandstone, or any other variety? Why must cement work



THE AQUARIUM BUILDING AT THE MILAN EXHIBITION.
Ground Floor Plan.

be, always completed with a smooth face or at most a floated sand finish or rough cast ? Surely we are ignoring the capabilities of the material when we restrict ourselves to one only of the many possibilities that it affords. A similar line of argument would forbid the use of iron in the reinforcement of concrete, but just as we are only now, at any rate in England, awakening to the constructional possibilities of the combination of steel and concrete, so are we as yet ignoring the potentialities of the surface treatment of cement.



The Aquarium Building at the Milan Exhibition.
Basement Plan and Section A-B.

Various operations on wet plastering are admitted on all sides, as legitimate modelling, stamping, incising, and graffito. Why not then the use of material to produce varied texture as well as modified form of surface ? And if it is allowable to work wet surfaces, why not dry ? Why not cement instead of lime stucco ? From a logical and impartial standpoint, there seems therefore no valid objection to our following the suggestions that are to be found in Milan.

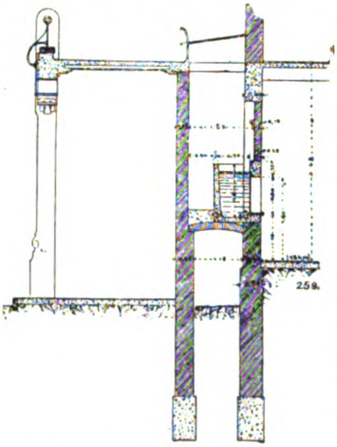
Turning now to the constructive aspect of our subject as illustrated in the Milan exhibition, we find little beyond the Aquarium building referred to above In this, of which we give. plans of ground floor and basement as well as sections showing the general construction, reinforced concrete has been used for the three large underground water tanks for the storage of sea water, which are shown in the basement plan and in section A.B. Two of these tanks have a capacity of 23 cubic metres each (about 175,000 gallons) and the largest one, between them, has a capacity of 85 cubic metres (about 350,000 gallons). These tanks are lined with plate glass. As may be seen from the ground plan the show tanks are arranged on either side of a semi-circular ended gallery. They are constructed of concrete with double sheets of plate glass and an intervening air space in order to maintain equability of temperature.

The open external colonnade around the building shown in section C.D. is also constructed in reinforced concrete finished as before-mentioned in cement treated with quasi masonry surface

The decorative treatment of the exterior designed by the architect, Locati, is of high artistic merit, more restrained than the less permanent structures by the same architect and, to our thinking, more successful. The motifs for the decoration are taken from the forms of marine animal and vegetable subjects. The execution of this exterior decoration was entrusted to Professor Chini, of Milan.

We find some exhibits in form of illustrations of works carried out on various systems, but that is all, and these illustrations are mere pictures and not in the form of working drawings.

It is, however, regrettable to learn from the architectural room that the advantages of the reinforced concrete pile have not as yet impressed the Italians to the extent that is desirable in the interests of all lovers of art, for in the exhibition at Milan is a fine collection showing the work that has been done, and that is still in progress in dealing with the foundations in Venice of the campanile of St. Mark, the palace of the Doges, and other notable buildings. There can be no doubt that Venice is now suffering from the long delayed but inevitable decay of the timber piles that form the support of her beautiful buildings. There is not a campanile in Venice that is not more or less out of the vertical, and many other buildings, particularly amongst the older examples, give striking evidence of instability. The threatening catastrophes would doubtless long since have occurred but for the enormous number of the closely packed wooden piles that are the foundation of Venetian buildings. Yet we see the same type of wooden piles being used to-day, when the reinforced concrete pile has practically proved its imperishable nature.



259.

AQUARIUM BUILDING.
Section C D.

A remarkable development in the use of reinforced concrete is found in the Milan exhibition in what we may call accessories.

The Societa Anonima Reggio-Emilia, the Societa Lodigiana, and other exhibitors, show examples of baths, sinks, cisterns, tables, pipes, both socketted and flange jointed, steps and landings.

The usual method of constructing these is by means of light ordinary wire netting of about ½ in. mesh embedded in concrete of natural or Portland cement and fine ballast or coarse sand The thickness for cisterns and sinks varies according to size from ½ in. to ¾ in., that of baths from 1½ in. to 2½ in. For these latter marble chippings are sometimes used, and the surface polished by hand, and the same method is adopted for tables and other objects for which a good and ornamental appearance is desired. The thickness of pipes varies with the size from ½ in. for small ones upwards. So also with circular tanks, the thickness of which ranges from ½ in. up to 3 in. for those 15 ft. diameter.

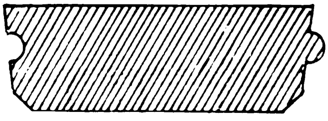
In steps and landings, copings and other more strictly constructive features, iron rods, generally ¼ in. diameter, are used for the reinforcement, and these are also employed in connection with wire netting for large tanks and pipes.

Francesco Pozzi e Figli shows models of reinforced concrete sewers of oval section. These are made up to as large as 23 ft. by 11 ft. 6 in., but in many cases the bottoms are lined with glazed stoneware, and the junctions for incoming drains are also formed of the same material. For all hydraulic work it seems to be the general practice to apply the reinforcement in the form of wire netting, whether supplemented or not by small iron rods.

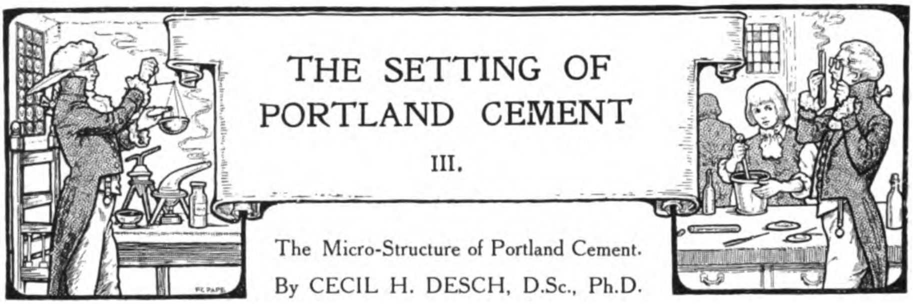
There seems to be scarcely anything which the Italian is not ready to make in reinforced concrete. Railway sleepers one can readily understand, their superior durability to wood outweighing the extra cost, and thousands are in use in Italy; telegraph poles also, which are made 24 ft. high, 11 in. diameter at bottom, tapering upwards, of 1½ in. thickness, with 24 rods ¼ in. diameter; but what are we to think of barges and lighters? It is interesting to learn that for small craft the cost of these is one-and-a-half times that of wood, and one-third less than that of iron, but when a size of 90 to 100 tons burden is reached, the cost is no more than that of wood.

Perhaps, however, the most striking example in the extended use of concrete is the exhibit of Adrianno Petracchi, of Milan, in the agricultural section of the exhibition, who shows large vats or tuns for the storage of wine or oil. Curiously these are made in staves, the section of which we show below, and which are 7½ in. average width, and 2¾ in. thick. One of these tuns, by way of example, is 7 ft. high, 5 ft. 10 in. diameter at top, and 6 ft. 4 in. at bottom, external measurement. The staves are put together with an oleaginous luting, and are held together by two iron bands or hoops 3½ in. wide by ⅛ in. thick. The top, which is loose, is 5 ft. 6 in. diameter, and 2 in. thick, with a circular hole 18 in. diameter. The tun is fitted with a metal cock for drawing off the contents. The remarkable point that is so curious about these productions is that although the maker is so ultra modern in the use of material, he is still so fettered by tradition that he has adopted the old-time construction of staves and hoops necessary in wood instead of the cheaper and more skilful method of monolithic reinforced concrete, which he can scarcely be unaware is in use for cisterns and tanks even larger than his own productions. The interesting points of this exhibit is that the modern Italian is firmly impressed with the idea that cement is more suitable, more durable, and more hygienic for the storage of liquids than wood.

We learn from the work of the modern Italian in Milan that the potentialities of cement and reinforced concrete are almost limitless, both artistically and constructively; that it may take the place of stone, brick, wood, and rolled steel; that it is capable of a high degree of artistic treatment, and adaptable to the construction of almost every conceivable article.



CONCRETE WINE VATS.
Section of stave



THE SETTING OF PORTLAND CEMENT

III.

The Micro-Structure of Portland Cement.

By CECIL H. DESCH, D.Sc., Ph.D.

To all engaged in constructional engineering, and more particularly in the application of concrete and reinforced concrete, the question of the setting of Portland cement is one of the utmost importance. Having regard to this, arrangements have been made by which a series of articles will be presented by well-known authorities at home and abroad, dealing with the question in its chemical and physical aspects, and these various articles will finally be summarised with the view of presenting the more important facts and the consensus of opinion. The attention accorded to the earlier article has encouraged us to extend our list of contributors on this subject to the leading authorities of other countries. Correspondence is invited, as a free discussion of the various arguments put forward will be welcome to all who have this subject at heart.—ED.

THE chemical and physical methods employed in the study of the constitution of Portland cement, and of the reactions involved in the process of setting, which were briefly outlined in the March and May issues of this journal, have gained a powerful auxiliary in recent years in the shape of the microscopic method of research. The examination of thin sections of rocks under the microscope, introduced by Dr. Sorby in 1856, enables the mineralogist and the geologist to observe, not only the crystalline form, colour, and other physical properties of the visible constituents, but also, by means of polarised light, their internal structure. Since the constituents of Portland cement are mostly transparent in thin layers, the method is applicable in this case also.

Owing to the brittleness and porosity of the cement clinker, the preparation of satisfactory thin sections presents some difficulty, but the procedure does not differ esentially from that prescribed for the more friable varieties of rocks. The consequence of this brittleness is, however, that the sections rarely yield satisfactory photographs, the thickness being such that there is generally some overlapping of the crystalline grains. More detail is therefore seen when using the microscope for eye observations than can be reproduced in a photograph. The complete determination of the constituents of a cement section requires the examination of the action of polarised light, and a microscope fitted for that purpose is therefore required. By introducing a drop of water or of a solution of a salt at the edge of the section, the progressive action on the different microscopic constituents may be watched, and this micro-chemical method gives valuable information as to the share taken by each individual constituent in the setting of the cement.

The most conspicuous substance observed in any section of well-burnt clinker forms colourless, highly refractive crystal grains, showing weak double refraction. The outlines of the grains are approximately hexagonal, but always more or less rounded, so that measurement of the angles is not possible. Optical examination, however, shows the crystals to belong to the rhombic system, with hexagonal habitus. To this constituent Törnebohm gave the name of Alite, and a study of the action of water and salt solutions shows that it is the substance primarily concerned in the setting of cement, being readily attacked by reagents. The diameter of the grains is about 0·003 mm., and they are usually smaller in rotary clinker than in that burnt in vertical kilns.

Around and between the alite crystals are seen rounded grains, varying in colour from yellow to greenish-brown, and rarely showing any crystalline faces.

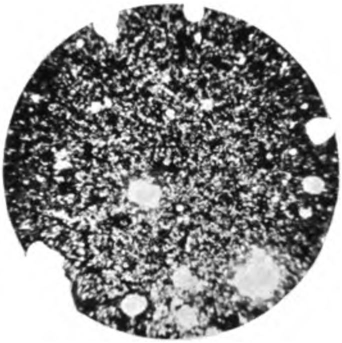


Fig. 1. Portland Cement Clinker.
× 40 diam.

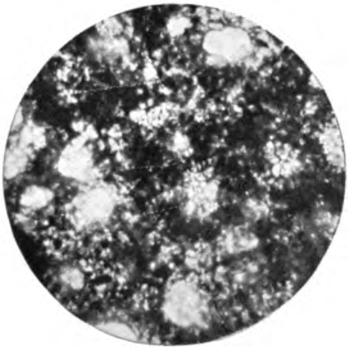


Fig. 2. Portland Cement Clinker.
× 400 diam.

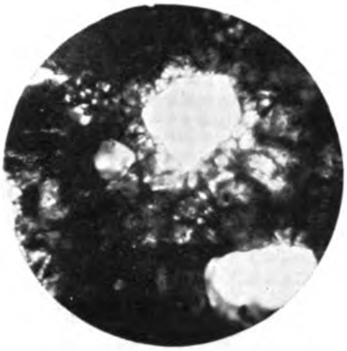


Fig. 3. Portland Cement Clinker.
× 400 diam.

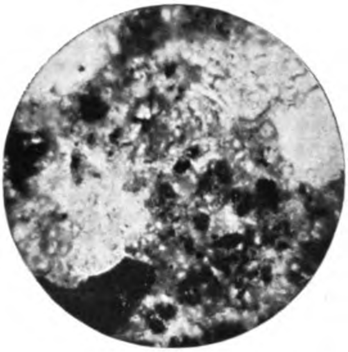


Fig. 4. Portland Cement, hardened under Water.
× 400 diam.

This constituent, to which the name Celite is given, shows strong double refraction. Chemical examination proves, what their colour already suggests, that these grains contain the greater part of the iron, and in fact their quantity may be increased by adding ferruginous materials to the mixture before burning. Celite is only slowly acted on by water. The alite and celite can be distinguished clearly in the photographs, especially in *Fig.* 3. These two are the invariable constituents of cement clinker, but other substances are often observed. The most important of these accessory constituents is Belite, which forms yellow, turbid grains, showing fine cleavage lines inclined at an angle of 60 deg. Belite is most abundant in cements, poor in lime, and also in the external crust often found on masses of clinker, due to the action of silicious substances present in the lining of the kiln. It frequently disintegrates spontaneously, and therefore appears to contain a dicalcium silicate.

A fourth constituent, Felite, forms very minute, colourless crystals, with strong double refraction. It is never abundant, and occurs principally in under-burnt cements. Richardson, it should be said, describes a similar constituent under the name of belite, and it must be admitted that considerable uncertainty prevails as to the properties of these crystals, which only occur sparingly. Many sections of clinker show abundant groups of slender rods, usually grouped in sheaf-like forms. Törnebohm regards these as a form of celite ; Richardson, on the other hand, as a modification of alite. Owing to their small thickness, I have not found it possible to isolate them sufficiently to examine their optical properties, but a good deal of interest attaches to them from a physico-chemical point of view.

Some observers have described an optically isotropic substance filling the interstices of the clinker, and having the properties of a glass, but, considering the difficulty of a complete optical examination, the evidence is insufficient to establish the presence of any such glassy magma. Crystals of calcium oxide (free lime) are never observed. *Figs.* 1, 2, 3 represent photographs of average specimens of good commercial clinker, the rounded gas cavities produced by the escape of carbon dioxide during the reaction can be clearly seen, and the alite (light) and celite (dark) can also be distinguished. These photographs were taken in ordinary (non-polarised) light.

More perfectly developed crystals of alite and celite may be obtained by fusing together the materials in the laboratory. Schmidt and Unger have in this way obtained well-developed crystals of alite 0·4 mm. in diameter. Their investigations leave no doubt that alite is a solid solution of calcium aluminate in tricalcium silicate. The synthetic product hardens with water, showing all the properties of a good, slow-setting Portland cement.

The microscopic examination of cement which has been mixed with water and allowed to set has been less systematically pursued than that of the clinker. *Fig.* 4 shows a section cut from a pat of Portland cement hardened under water. The most striking constituent of hardened cement is calcium hydroxide, which separates as a product of hydration in large, plate-like crystals, some of which are easily seen with a hand lens, and under favourable circumstances may even reach a length of several millimetres. The other principal product of hydration, mono-calcium silicate, forms a network of slender needles, interlaced in such a way as to make the study of their optical properties difficult or impossible. In addition to these, dark masses of unaltered celite and accessory constituents may be recognised as dark masses in the photograph. The question of the presence of aluminium hydroxide and of gelatinous silica in the hardened cement must be regarded at present as an open one, much work remaining to be done before a complete knowledge of the microscopic constituents is attained. The indications in this brief note may perhaps serve to call attention to the importance of the subject.

I am indebted to Mr. H. W. Anderson, C.E., for the loan of several microscopic slides of cement clinker from his collection.

Reinforced Concrete Bridges.

II.

By **W. NOBLE TWELVETREES, M.I.Mech.E.**

In no Department of constructional engineering has reinforced concrete been found of greater service than in that of bridge work, and although Great Britain can only show but few examples of reinforced concrete bridges, they can be counted by hundreds on the Continent of Europe, and in the United States. In the present series of articles the author summarises the primary features of the most useful types of reinforced concrete bridges with the view of demonstrating the many forms available for the British designer.—ED.

ALTHOUGH once regarded with a certain amount of suspicion, the combination of concrete and steel has been very largely employed by bridge builders in almost every part of the world, and its use for this particular purpose is by no means unknown in our own country. Various examples have been illustrated in the preceding article, in connection with which the present one should be read as a continuation.

MARYBOROUGH BRIDGE, QUEENSLAND.

Another method of reinforcing concrete arches was introduced in 1884 by Robert Wünsch, a Hungarian engineer, who employed rolled sections to form a type of framework suitable for a flat-topped arch. Several bridges have been built on the Continent with reinforcement of this kind, and an excellent example is to be found in the Maryborough Bridge, Queensland, built from the designs of Mr. Alfred B. Brady, M.Inst.C.E., of the Public Works Department of that country.

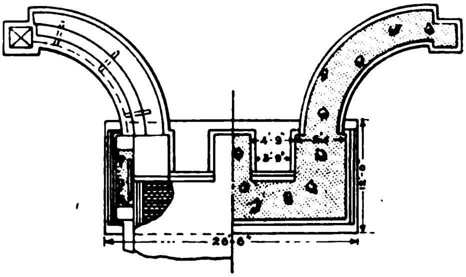


FIG. 13. MARYBOROUGH BRIDGE, QUEENSLAND.

Fig. 12 is a half elevation of this bridge, which has a total length of 615 ft., and a waterway of 595 ft. between the abutments. The width of roadway between the parapets is 20 ft. 8 in., and the width between the faces of the arches is 22 ft. 8 in. The bridge includes eleven arches, each with the clear span of 50 ft., and a rise of 4 ft. or 0·08 of the span; the thickness of concrete at the crown of each arch is 20 in. at the centre of the roadway, and 18 in. at the parapets, the thickness at the haunches along the centre line being 5 ft. 8 in. *Fig.* 13 contains a half plan and a half horizontal section of the abutments and wing walls, which are of

Portland cement concrete in the proportions of one part of cement, two parts of clean sharp sand, and five parts of hard stone, broken to a 2 in. gauge, and are supported upon hard wood piles with wrought-iron shoes. Each of the ten piers consists of two rectangular columns with semi-circular ends above low water level, and connected by a solid arch, as shown in *Fig.* 14. Most of the concrete in the piers was in the proportions of 1 : 2 : 5, but the proportions of 1 : 1½ : 4 were adopted about the cutting edge of the caissons used in construction, and for the upper part of each pier.

To provide for any tension resulting from flood pressure of water upon the up-stream face of the bridge, a rail of the Vignoles pattern, weighing 60 lb. per yard and 20 ft. long, with suitable cross bars attached, was built into each pier.

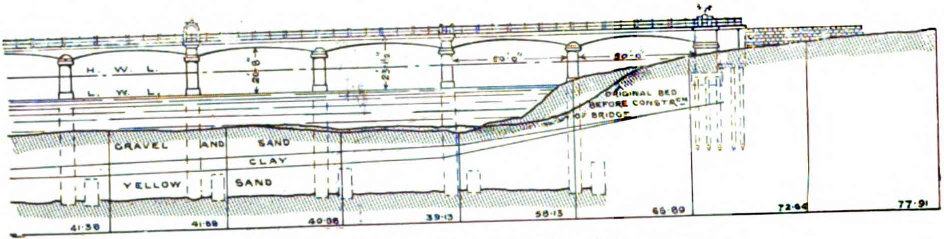
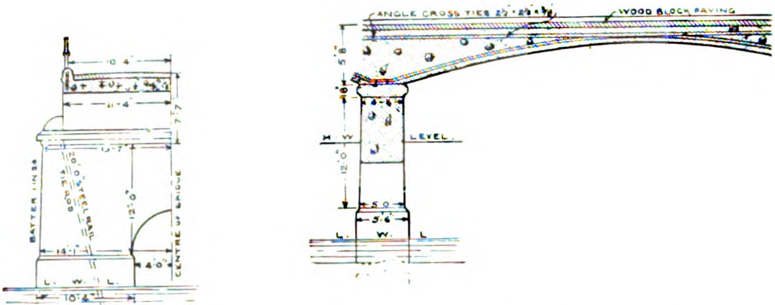


FIG. 12. MARYBOROUGH BRIDGE, QUEENSLAND.
Elevation.



FIGS. 14 AND 15. MARYBOROUGH BRIDGE, QUEENSLAND.
Details.

Similar rails were provided in each abutment, being placed transversely to the main axis of the bridge. With the exception of these rails the piers and abutments are without reinforcement.

In the superstructure, the concrete was mixed in the proportions of one part of Portland cement, one and a half parts of clean sharp sand, and four parts of broken stone, of 2 in. gauge. The arches are segmental with a flat top, as in fig. 15, and they are reinforced by eleven continuous frames formed of Vignoles rails weighing 41½ lb. per yard, placed side by side, and spaced 2 ft. apart. Each frame consists of two members only—a horizontal top rail continuous for the entire length of the bridge, and curved lower rails bolted to a bedplate on each pier and abutment. The frames in each span and over each pier are connected transversely by 2½ in. by 2½ in. by ⅜ in. angle-bar ties, these having been applied chiefly for the purpose of stiffening and giving lateral support to the framework during the deposition and ramming of the concrete.

PASSAIC RIVER BRIDGE, PATERSON, U.S.A.

An interesting example of construction somewhat resembling the Wünsch arch, is furnished by a bridge over the Passaic river at Paterson, New Jersey. This is one of several bridges designed by Mr. F. W. Schwiers, of New York, to replace a number of highway bridges destroyed by severe floods in the summer of 1902. The special features claimed by the designer for this type of bridge are the combination of the arch and cantilever action of the concrete and the steel ribs, and the anchorage of the upper members of the ribs in the abutment masonry. The principle is said to have been suggested by the form of roof truss largely used in Germany, in which the top chord and the end verticals are connected with an arched lower chord, so as to form a combined horizontal span and two trussed columns, insuring rigid construction with a shallow depth at the crown. So far as the writer is aware, this is the first application of the principle to reinforced concrete bridges, and the contention of the designer is that it conduces to exceptional efficiency and economy, while giving a maximum headway and permitting the construction to be carried to a considerable height with comparatively narrow piers, thus obviating the massive masonry that would otherwise be necessary to resist the thrust of very flat arches.

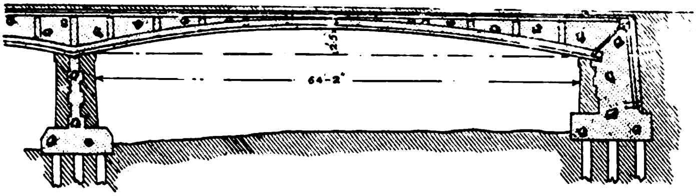


FIG. 16. PASSAIC RIVER BRIDGE, PATERSON, NEW JERSEY.

Fig. 16 is a part longitudinal section illustrating the details of construction. The bridge has a total length of 170 ft. 6 in. between the faces of the abutment walls, and consists of three slightly skewed arches with a clear span of 54 ft. 2 in., and a rise of only 2 ft. 5 in., the clearance above ordinary water level being about 10 ft.

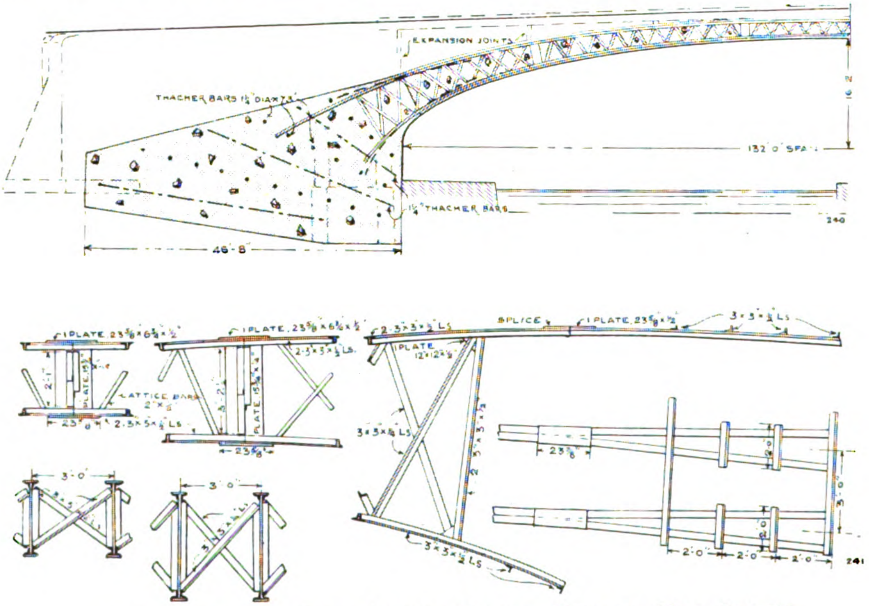
The reinforcement consists of eleven equidistant ribs, including two principal members parallel to the upper and lower surfaces of the concrete and connected by vertical steel plates forming panels about 5 ft. long. The ribs are continuous from span to span and the ends of the upper members are anchored by vertical bars built into the concrete of the abutments and forming the characteristic feature of the design. It is worthy of note that the design for this bridge was adopted in competition with another for a steel bridge, thus showing that reinforced concrete is quite capable of holding its own in respect of economical construction.

STEEL-FRAME CONCRETE BRIDGES.

A method of reinforced construction involving the use of rolled steel sections is to make and erect a series of stiff steel ribs, connected with a framed platform skeleton, which is then encased in concrete.

A good example of the kind is to be found at Auch, in France. This bridge was designed by M. Bonna, and consists of four steel arch ribs of 69 ft. span with a rise of about 6 ft. 7 in., the ribs being 1 ft. 3½ in. wide by 11 in. deep at the crown, carrying vertical steel columns cased in concrete, which in turn support the concrete-covered steel frame of the platform, measuring 14 ft. 10 in. wide, and two cantilever footwalks, each 2 ft. 5½ in. wide.

This is clearly a compromise between ordinary steel arch design and reinforced concrete design of the most correct type. There is every reason for hoping that it may be followed by engineers who do not feel disposed to surrender steel frame construction, not merely in bridge building, but in all other structures, because the concrete offers a sure defence against the slow decay of the metal by chemical action, and a reliable protection against injury by fire.



FIGS. 17 AND 18. PARK AVENUE BRIDGE, NEWARK, NEW JERSEY.
Section and Details.

But engineers who are willing to accept the undoubted fact that what we term "reinforced concrete" is really a combination constituting an entirely new structural material and not merely concrete reinforced by steel, will be wise to employ small bars instead of large sections, and to apply the bars only to those parts of the structure where the properties of the metal can be fully utilised. As a general rule, the parts in question are those where tensile and shearing stresses are developed, for the concrete is usually capable of resisting all compressive stresses.

THE MELAN ARCH.

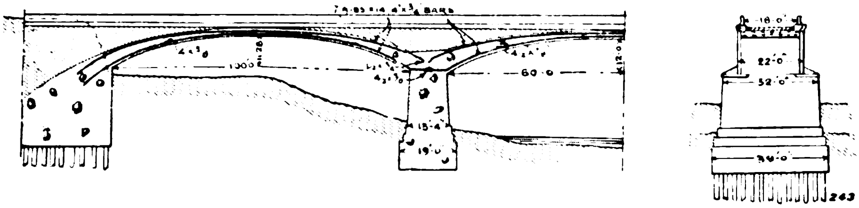
Few systems of bridge design have been more widely adopted than that introduced by Professor Melan, of the Polytechnic School of Brunn, Austria. Numerous bridges have been built on this system in Europe and between one and two hundred in the United States, since its introduction into that country by Dr. Ing. Fritz von Emperger, of Vienna, who is well known as one of the most eminent authorities on reinforced concrete.

As originally designed, the Melan arch consisted of concrete abutments, containing beams disposed transversely to the longitudinal axis of the bridge, and arch ribs consisting of strongly-built steel girders cased in concrete.

Dr. von Emperger was the first to recognise the fact that the web of the Melan steel ribs constituted a waste of metal, and patented an improved design in which the reinforcement was represented by bars placed near the upper and lower surfaces of the arch and connected by light bracing.

A similar idea has also been patented by Mr. E. Thacher, M.Am.Soc.C.E., the first American engineer to design arches of this kind in accordance with the theory of the elastic arch.

At the present time, the modified Melan arch is very largely adopted in the United States, and for this reason it will probably interest readers to have particulars of a representative example.



FIGS. 19 AND 20. JACAGUAS RIVER BRIDGE, PORTO RICO.

PARK AVENUE BRIDGE, NEW JERSEY.

Fig. 17 is a half sectional elevation of the Park Avenue Bridge at Newark, New Jersey. The total length of the structure is 243 ft. 7 in., the arch having the clear span of 132 ft. with a rise of 16 ft. 2 in., and the maximum clearance of 22 ft. 6 in. The total width is 74 ft., comprising a roadway 40 ft. wide, and two footwalks 15 ft. wide each, the reinforcement being built up of ordinary rolled sections and plates, in the manner shown by the details in *Fig.* 18. The abutments are reinforced with 1¼ in. diameter Thacher bars, some parallel and others perpendicular to the axis of the bridge. Similar bars constituting the reinforcement to the end of the arch ring, near the upper and lower surfaces of the concrete. Under stresses not exceeding 1,800 lb. per square inch, the steel ribs are capable of taking the entire bending moment of the arch without any aid from the concrete, the permissible stresses in which were assumed at the following values, exclusive of temperature stresses in each case: Compression, 500 lb. per square inch; tension, 50 lb. per square inch; shear, 75 lb. per square inch.

The Park Avenue Bridge contains about 6,200 cubic yards of concrete, 106 tons of steel ribs, 18 tons of Thacher reinforcement bars, and some 2,000 square yards of mortar facing on the exposed surfaces. Construction was commenced in August, 1904, and the centering was struck in January, 1905. Measurements taken at 10 points in the length of the bridge showed the maximum deflection at the crown to be 0·99 in., with uniformly decreasing deflection towards the springings. This bridge is one of the two built for the Essex County Park Commission from the designs of Mr. A. M. Reynolds, Jun., the architectural features having been designed by Messrs. Babb, Cook and Willard of New York.

Another modification of the Melan arch is one in which the principle of the hinge is introduced. Many three-hinged bridges of reinforced concrete have been built on the Continent, among which may be mentioned one at Steyr, with a span of 139 ft., and another at Laibach, with a span of 108 ft., the system of articulation being similar to that employed for steel arches. Owing to the fact that no bending moment exists at the hinges except that due to friction, the depth of the springings need only be sufficient to transmit the thrust to the hinges. Thus a considerable saving of material can be effected, and the hinged construction has the further advantage of obviating the formation of cracks in the abutments and piers in case of settlement. On the other hand, it must be admitted that hinges reduce the rigidity and tend to increase the deflection of an arch.

The essential characteristics of the Melan bridge designed in accordance with Mr. Thacher's patent may be thus described. Two pairs of steel bars are used to form a beam, each pair consisting of two horizontal parallel bars connected at intervals, while the two pairs one below the other, have no connection except the concrete in which the whole is embedded. The bars thus take the place of the flanges in an I-girder, while the concrete performs the function of the web and takes the shearing-stress, which it is easily capable of doing.

PORTO RICO BRIDGE.

Fig. 19 is a half longitudinal section of a bridge built by Mr. Thacher across the Jacaguas River, Porto Rico, and will serve to make clear the details of his system. This bridge has three arches, one in the centre with a span of 120 ft. and a rise of 12 ft., and one at each end with a span of 100 ft. and a rise of 11·28 ft., the total length being 404 ft., and the width between parapets 18 ft. (*See Fig.* 20.)

Work was commenced in February, 1900, and the bridge was completed in March, 1901. The centering of the west span was lowered two months after the completion of the arch, the deflection then being 0·31 in., gradually increasing to 0·75 in., in sixty days, after which no further deflection was observed. The centering of the centre span was lowered after an interval of forty days, the deflection then being 0·62 in., which decreased to 0·875 in., in one month. The centering of the east span was lowered after an interval of thirty days, when the arch showed a deflection of 0·75 in., increasing to about 1·25 in., in two months.

Just before completion the bridge was tested by the Board of Public Works in the following manner: Bags of sand and a number of men, representing a maximum weight of 23·5 tons, were concentrated at the centre and intermediate points of the east span and at the crown of the centre span, the observed deflection being about 0·144 in., for the 100 ft. span, and 0·180 in. for the 120 ft. span. Mr. Thacher afterwards conducted a test by loading all the spans with as many carts as could be crowded on the bridge two abreast, all the carts being heavily loaded with stone, while bags of sand were piled against the parapets. Under

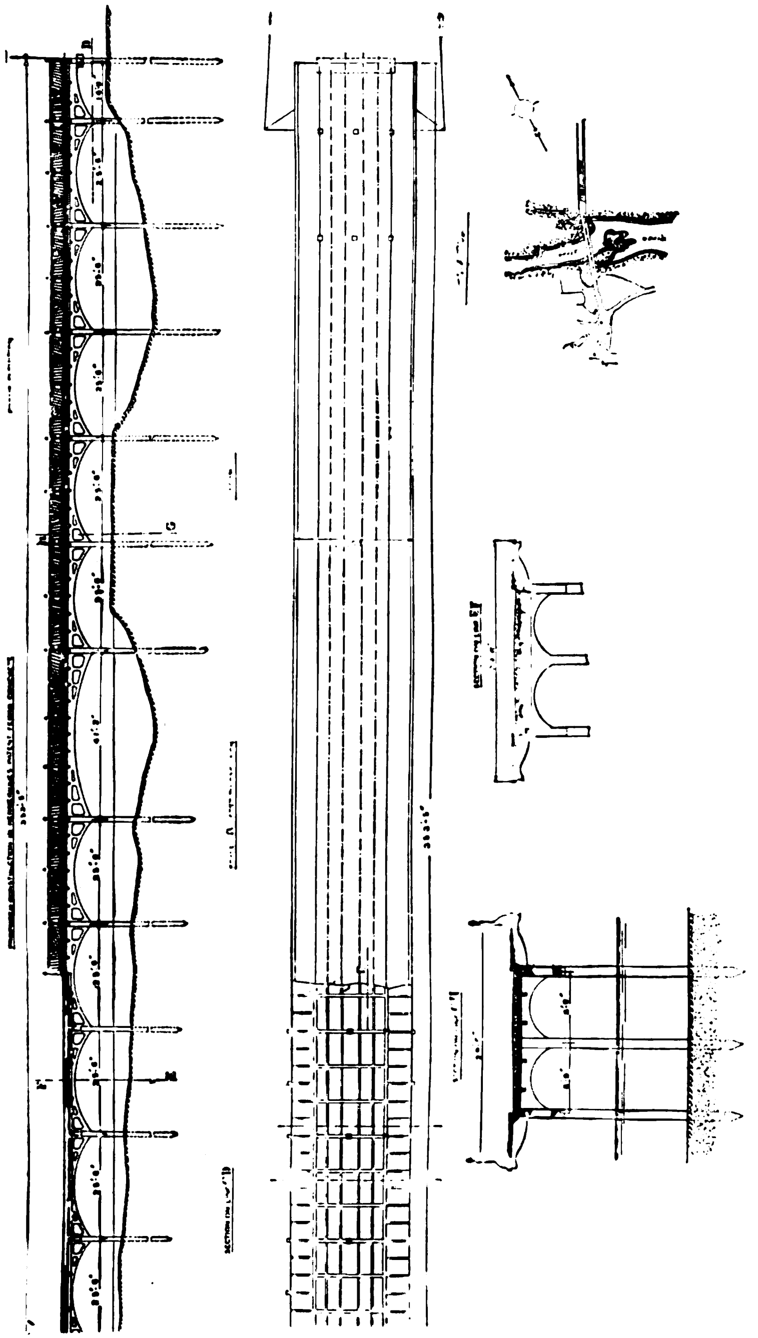


FIG. 21. TUCKTON BRIDGE, BOURNEMOUTH.

From the Hennebique Catalogue, 2nd Ed.

this load the deflections were as follows: West span, 0·006 in.; east span, 0·004 in.; centre span, 0.016 in. Although the exact weight of the last-mentioned load is not stated, it is evident that this must have been many times greater than those likely to result from any ordinary traffic across the bridge.

TUCKTON BRIDGE, BOURNEMOUTH.

This is the first reinforced concrete bridge of its kind in this country, and was rendered necessary by the extension of the Bournemouth system of electric tramways to the neighbouring town of Christchurch.

Fig. 21 contains various drawings of Tuckton Bridge, and among them is a key plan showing the situation of the bridge in relation to the River Stour. The old bridge at the same place was a timber structure, too narrow for modern requirements and far too weak for tramway traffic.

In April, 1904, half of the old bridge was taken down, the other half being left for traffic while the first half of the new bridge was under construction.

As will be seen by the longitudinal elevation, the total distance from bank to bank of the river is 353 ft. 5 in., this distance being spanned by twelve segmental arches, and two semi-arches, one of the latter type at each end. One arch at the deepest part of the river channel has the span of 41 ft. 2 in., the other arches being of 25 ft. 6 in. span, and the two semi-arches measuring 14 ft. 9 in. and 16 ft. 3 in. respectively from pier to abutment.

The substructure is formed of 15 in. by 15 in. reinforced concrete piles, driven in three longitudinal rows spaced 8 ft. 9 in. apart, as shown by the cross section. The piles in the two outer rows are jointed at the top, longitudinally by the arch ribs and transversely by other arches. The overall width between the outer faces of the piles is 19 ft., but the width of the bridge platform is increased to 29 ft. 6 in. between the parapets by cantilever brackets, supporting two 6 ft. footways. The roadway is 17 ft. 6 in. wide, and carries two tramway tracks.

The arch ribs were formed with openings in the haunches serving to reduce weight and adding considerably to the lightness and elegance of the structure.

All the arch ribs are about 5 ft. deep at the springings and 2 ft. 3 in. deep at the crown. The arches connecting the piles transversely are 3 ft. 9 in. deep at the springings by 1 ft. 9 in. deep at the crown, by 9 in. thick.

Between each group of three piles, the arch ribs are connected by two transverse beams, and the groups of piles are connected longitudinally, as shown in *Fig.* 21. Over the system of supports formed by the upper surfaces of the arch ribs, the transverse arches, the transverse beams, and the longitudinal secondary beams, there is a 6-in. slab of reinforced concrete forming the decking of the bridge. The floor slab of each footway is 5 in. thick and is connected with the main structure by a course of reinforced concrete extending outwards as shown in the transverse sections.

The bridge was built on the Hennebique system of ferro-concrete, from the designs of Mr. F. W. Lacey, M.Inst.C.E., the borough surveyor of Bournemouth, by the Yorkshire Hennebique Construction Company, of Leeds.

(*To be continued.*)

Reinforced Concrete Railway Sleepers.

By G. H. KIMBALL,

Chief Engineer, Chicago and Alton Railway, U.S.A.

Seeing that the scarcity of timber suitable for railway sleepers is making itself felt in many parts of the British Empire and that rapid depreciation of the existing timber sleeper has generally become a veritable nuisance to engineers in charge of permanent ways, the problem of finding a suitable substitute is becoming a very important one. We have touched upon the subject of introducing reinforced concrete sleepers in our first issue under "New Uses for Concrete." In this number we present, by the courtesy of the "Cement Age" a special article on putting forward the American aspect of the question. This article will shortly be followed by one on the Italian aspect, for the Italian railways are now introducing the reinforced concrete sleeper on a large scale.—ED.

IT is the purpose of this article to consider briefly the present status of the sleeper question. It is a serious matter, which is rapidly growing in importance, and is receiving more and more attention from year to year. Clearness and convenience seem to naturally indicate its treatment under the three sub-divisions of timber, steel and concrete.

TIMBER SLEEPERS.

For the present, at least, the importance of this phase of the subject holds first place, and it is well to ascertain what is to be expected in this direction. All concerned recognise that the limited and rapidly receding supply of timber has already caused timber sleepers in general to become poor in quality, small in size and high in price, and if the standards of a few years ago were to be maintained, the price would be practically prohibitive. The grades of timber desirable for this purpose have become far too valuable for other purposes to permit the use of any but inferior materials.

It will be of value in this connection to see what the prospect for relief may be. Aside from the use of steel, of concrete, or some combination of those two materials, the only alternative is in the growth of timber for this purpose, and its use, preserved or otherwise, with sleeper plates.

Recent information, received from the Bureau of Forestry, U.S. Department of Agriculture, may be summed up as follows:—

Among the plans proposed the following are the most promising and important:—

1. The purchase and careful management of existing forest tracts.
2. The use of inferior timbers by means of preservatives and sleeper plates.
3. The planting of treeless areas.

It is believed that the solution of the problem lies not in any one of these methods, but in a combination of them all.

THE QUALITIES OF A TIMBER RAILROAD SLEEPER.

A timber to be valuable for sleeper purposes must possess the following qualities:—

1. It must furnish a sleeper which will give continuous service for from five to eight years, otherwise the expense of renewal will be too great.

2. It must not be so valuable for lumber that it cannot be cut for sleepers.

3. It must be of rapid growth so that it will reach a suitable size in a short time.
4. It must renew itself easily after cutting so as to maintain the forest without much expense.

Whether these conditions can best be met by planting or the management of existing timber lands will depend upon the region. In many cases it will probably be necessary to start the forest by planting.

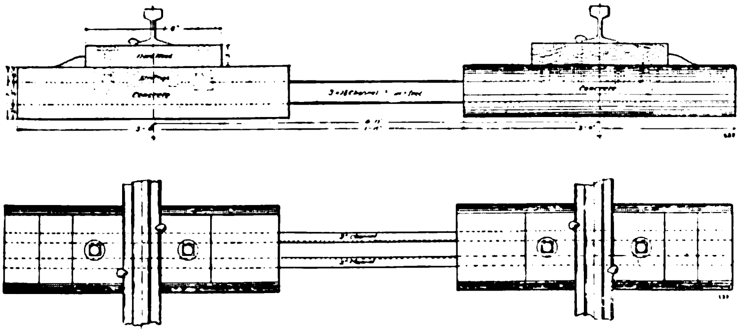
So far no railroad plantations have reached a sufficient size to furnish material for sleeper purposes, though certain catalpa plantations have yielded a large revenue from the sale of fence posts.

At present it does not appear that it is practicable for a railroad to attempt to raise its entire supply of sleepers.

In a well-managed forest of the faster growing woods a harvest of sleepers can be secured in about thirty years, on the poorer soils in about forty years, and the yield should be from 300 to 500 per acre, depending upon soil conditions, species used, etc.

SOME RECENT EXPERIMENTS BY RAILROADS IN FORESTRY.

The most important railroads which have actually gone into this question in earnest and are actually carrying on experiments are the Louisville and Nashville R. R., the Illinois Central R. R. and the Penna. R. R. While in cases where the trees planted are not doing especially well, it is mainly due to a lack of sufficient cultural knowledge on the part of those having the plantations in charge.



Plan and Section of Reinforced Concrete Sleeper.

The consumption of sleepers in this country is over 100 millions a year, and under present methods about 500,000 acres of land are being cut over annually to keep up the supply.

The writer has quoted the above in substance from the source already indicated, which is certainly authoritative.

It appears that our main reliance must be upon tree planting; but no results have so far been obtained, and the experiments now under way are lacking in the promise of complete success.

To ensure our sleeper supply from tree planting would require, at least (estimating 400 trees per acre after 30 years' growth), the planting of 250,000 acres per year for the next thirty years (7,500,000 acres) before a crop could be harvested. This takes no account of the increase in demand for the next thirty years, neither in allowance made for the visible supply.

Does any one believe that the present supply of timber will take care of the demand and take care of the increase for the next thirty years? Then how long will it take to organise this enterprise and get it started on a successful footing? It is manifest that the sleeper problem, so far at least as timber sleepers are a factor must soon reach a crisis.

THE ULTIMATE SOLUTION OF THE RAILROAD SLEEPER PROBLEM.

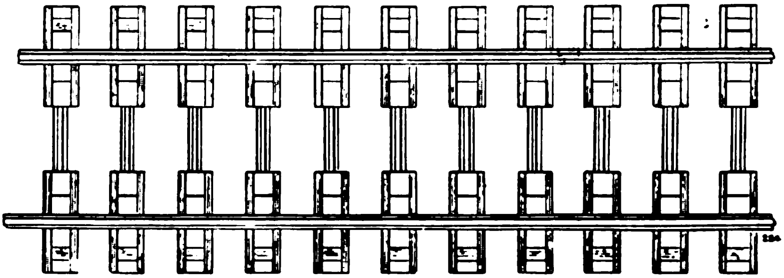
To the writer it seems that while preservative processes and tree planting are well enough in a way, and serve a good purpose, they are, so far as this question is concerned, but makeshifts after all, and can only put off the day of reckoning, which is inevitable.

The most that can be said of the work so far accomplished by preservative processes, is that the life of sleepers is prolonged for a brief time at a corresponding increase in cost. The loss and labour incident to sleeper renewals still remain.

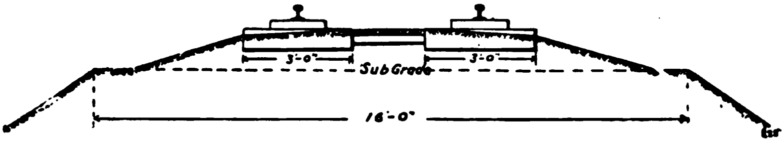
The real demands of the day with reference to permanent way so called, are that track construction be made really " permanent " in some reasonable definition of that term. For this purpose steel sleepers have been used.

THE COMPARATIVE MERITS OF STEEL SLEEPERS.

By steel sleepers I mean only those not combined with concrete. The only form of steel sleeper that merits attention is that now under experiment by the New York Central and Hudson River Railroad, the Pennsylvania Railroad and the Lake Shore and Michigan Southern Railroad. These sleepers were put in late in the season of 1904, and consist of a section of I beam rolled for the purpose and of the following dimensions: Length, 8 ft. 6 in. ; depth, 5½ in. ; top flange, 4½ in. ; bottom flange, 8 in. ; weight per foot, 19·7 lb. ; cost in small lots, $2.25.



PLAN OF RAIL AND REINFORCED CONCRETE SLEEPERS.



CROSS SECTION OF PERMANENT WAY.

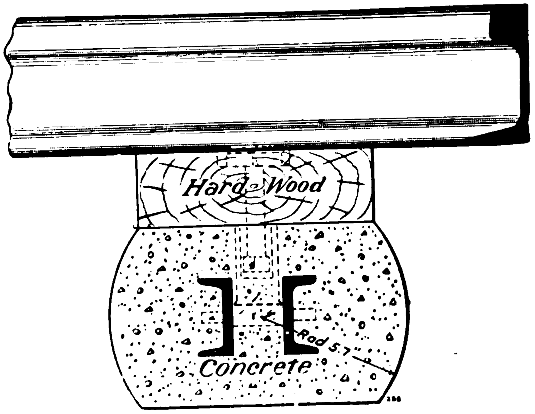
This sleeper is the outgrowth of the Buhrer " rail " sleeper, so called, where a piece of old rail was used inverted, with a plate secured to the head, thus forming the bearing surface in the ballast, the track rails being secured to the base of the piece of old rail forming the sleeper. (*See* No. 1, p. 56.)

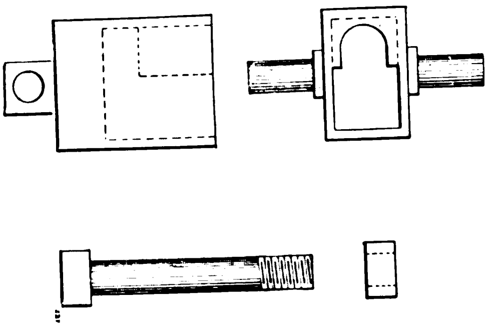
Possibly it is too soon to make definite conclusions concerning the use of this I beam, but some things are clear. Much difficulty has been experienced in securely fastening the rails to these sleepers, and suitable fastenings have yet to be devised. As now arranged, they consist of bolts passing through the top flange of the I beam used is a sleeper, and hold clips formed to fit the base of the rail. A wooden shim is sometimes used on top of the sleeper. The passage of a single train has been known to throw the track seriously out of gauge, and reference is not made to an isolated case.

The insulation, where these sleepers have been used in bonded track, has proven somewhat unreliable. Rail anchors have been found necessary to keep the track from running, and a decided tendency has been developed to roll the sleepers in the road bed, thus disturbing the tamping and further straining the fastenings. Not much seems to have been done to preserve these sleepers from the drip of brine from refrigerator cars and the actions of the elements. It still remains to be shown what the effect of derailment will be. Unless the same support is furnished as by timber sleepers, which is hardly to be expected, the result is sure to be more disastrous to train as well as track.

STEEL AND CONCRETE-STEEL RAILROAD SLEEPERS.

Under the head of concrete sleepers, a careful distinction should be made between steel-concrete sleepers and concrete-steel sleepers, the difference being determined by the predominance of one or the other of these two materials. This difference is vital. An illustration is found in the Buhrer rail sleeper before referred to. At one stage of the experiment Mr. Buhrer removed the plate from his sleeper and encased the rail in concrete. The section of the concrete was relatively small, the bearing coming directly on the steel and the vibration of the structure was determined by the steel, with the result that the concrete was at length shattered.





DETAILS OF FASTENINGS.

In most of the attempts to make so-called concrete sleepers it has been assumed to be necessary to make them of full length. As a natural consequence they have first broken in two near the centre because of the transverse stress at that point.

The fact is that in all of our track construction the pressure on the sleepers is eccentric with reference to the base of the sleeper; that is, the centre of pressure and the centre of figure do not coincide. For this reason, and without exception, the *ends* of the sleepers in all of our tracks are more or less loose in the ballast, in a position above and free from the bed except when under load. Doubtless sleepers of full length can be made to carry the load and distribute the pressure, but it is needless, and the cost would be prohibitive.

PREVIOUS ATTEMPTS TO MAKE SLEEPERS OF CONCRETE.

There have been many fitful attempts to make a satisfactory concrete sleeper, but on all the information I have been able to obtain, with the exception to be referred to, efforts have been confined to full-length sleepers, and have all failed.

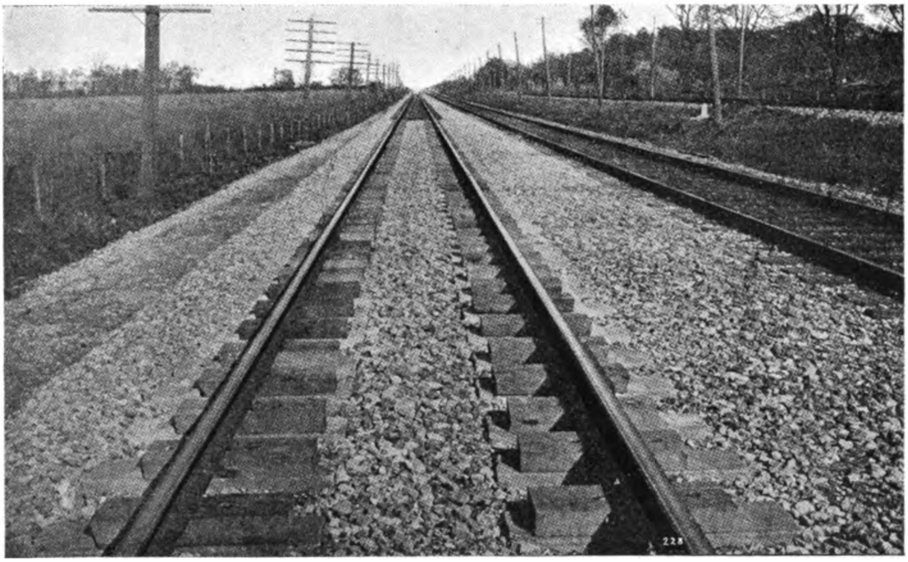
For this reason the idea prevails more or less that concrete is not a suitable material for this purpose, whereas failure is inevitable with long sleepers except at a prohibitive cost. The idea that concrete will not stand the shock of impact under heavy and high-speed trains is erroneous, for blocks of concrete even without steel, when properly designed and arranged, are capable of supporting the heaviest traffic.

The French roads in Indo-China have been using concrete for some years and to a large extent.

The writer's attempt to solve the problem began some years ago, and the subject has been pursued as closely as possible ever since. The design adopted and here described was completed and first put in track in November, 1901.

A SUCCESSFUL CONCRETE SLEEPER AND METHOD OF APPLYING IT.

It consists of two blocks of concrete, each three feet long, placed symmetrically under each rail so that the centre of pressure and the centre of figure of each section of the sleeper will coincide. These two blocks of concrete make one sleeper, and are rigidly connected by being moulded on the ends of a pair of three-inch channels weighing three pounds per foot. The channels are back to back, and spaced two inches apart in the clear.



Reinforced Concrete Sleepers, used since November, 1901.

The concrete blocks are seven inches thick and nine inches face, and the cross section is the same as that of a timber sleeper hewn or slabbed from a log about eleven inches in diameter. It presents the appearance in the track of an ordinary sleeper with a piece 2 ft. 11 in. long cut out of the centre.

Hardwood blocks, three inches thick, nine inches wide, and eighteen inches long, designed to cushion shocks, distribute pressure, support derailed trucks and serve as spiking blocks, are secured to the top of the concrete blocks. Each hardwood block is, of course, centred transversely to the line of the rail. Cast-iron sockets that also serve to space and connect the channels are moulded in place in the concrete, serve as an anchorage for holding down the hardwood blocks. These sockets receive suitable bolts, head down, so that when they are slipped to place and the holes through which they are introduced have been plugged, they cannot be withdrawn.

The first sleepers put in have been in service over four years, and small lots have been put in from time to time since. The last were put in the track of the Chicago and Alton Railroad in October, 1905. Of all the sleepers put in from first to last none have failed.

SOME PRACTICAL RESULTS THAT HAVE BEEN ATTAINED.

Three and one half years ago 1,700 of these sleepers were put in the track of the Pere Marquette Railroad in Bay City, Mich. The sleepers were put down on a concrete bed and each sleeper was set to the grade, being imbedded in a joint of cement mortar. The rails were then spiked down and the track filled in. I am informed by those in charge that there has been no change in the line, gauge or surface of the track.

The fact that concrete will stand in this form and under these conditions cannot be questioned. Good ordinary concrete is all that is required. All sleepers made up to date have been of concrete mixed in the following proportions.

Broken stone concrete:—

Cement	6 parts
Broken stone	11 parts
Sand or fine gravel	3 parts
Total	20

The broken stone passed through a 1½ in. screen and was clean and free from dust.

Gravel concrete :—

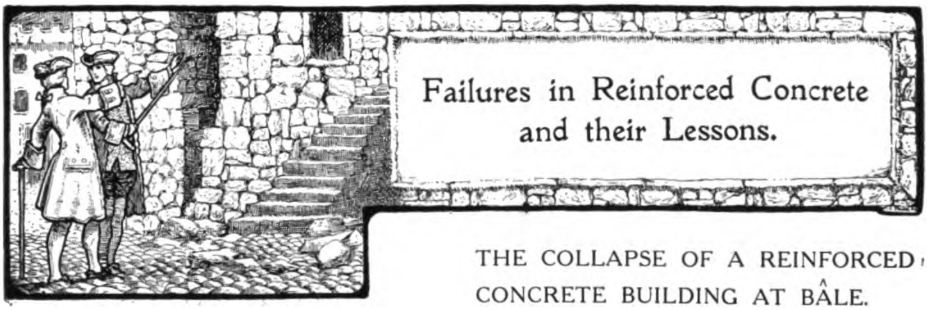
Cement	6 parts
Medium gravel	14 parts
Total	20

None of the pebbles to be larger than 1½ in. in diameter. Atlas cement was used principally.

The estimated cost and weight of these sleepers is as follows :—

Iron and steel, 52 lb. at 1⅛c...		$0.58
Concrete, 3 cubic feet, 374 lb. at $4.50 per yard ..		$0.50
Wood blocks, 7 square feet, 10 lb. at $17.00 per M. ..		$0.10
Totals	436 lb.	$1.18

It is not too much to claim that this affords a solution for the sleeper problem at a moderate cost, and offers large economies in wear of rail, ballast, and in track labour.



Failures in Reinforced Concrete and their Lessons.

THE COLLAPSE OF A REINFORCED CONCRETE BUILDING AT BÂLE.

At the Seventh International Congress of Architects, a Resolution was adopted at the suggestion of Mr. Max Clarke, F.R.I.B.A., to the effect that failures with Reinforced Concrete be independently investigated. We deal with the Resolution elsewhere, but as stated, we consider that reliable data as to failures must be of the greatest possible value to engineers, architects, and contractors alike, and even more so to the specialists connected with any work upon which there has been a failure. Only by full appreciation of any weakness in a system or method of execution, is it possible to limit the risk of accident.

The first example we present is one from Bâle, in Switzerland, that should prove instructive, and in presenting this example we would particularly refer all interested to the original report as a model of what an independent report of this description should be, comprising as it does some 32 quarto pages of carefully compiled facts and arguments. Our article is the summary of a free translation from the German of those 32 pages.

The system of construction here employed is not impugned, but the method of execution and the materials used. The question of responsibility as between the engineer controlling the reinforced concrete works and the contractor, touched on in the report, is one that claims special attention with us where builders who become licensees for specialist systems are frequently ignorant of the peculiarities of reinforced concrete and its constituent materials.—ED.

A NEARLY completed building at Aeschen, a suburb of Bâle, Switzerland, having collapsed on August 28th, 1901, with serious results, an official committee of experts was appointed to inquire into the causes of the accident. This committee, whose report is before us, comprised Herr A. Geiser, the city architect of Zürich ; Professor W. Ritter and Professor F. Schüle, of the Zürich Technical College. Their report is based on personal examination of the scene of the accident,on a thorough investigation of the plans and statical calculations employed by the builders, on the examination of witnesses, and on the results of a number of tests of materials carried out in the official testing laboratory at Zürich.

The building, described as the Restaurant and Hotel "zum Bären," occupied a site with a frontage of 18 m. (59 ft.) to the street, and a depth of 46·5 m. (152 ft. 6 in.), with an extension at the back at right angles to the main structure. The front portion of the building, 12·5 m. (41 ft.) deep, formed practically a separate structure, consisting of basement, ground floor, five upper floors and a roof loft, and the collapse was confined to this portion.

System of Construction.

The two party walls, the basement wall and foundations of the façade were of brickwork, the floors, columns, beams, etc., were in Hennebique reinforced concrete, and the façade was of reinforced concrete faced with red sandstone. Certain of the foundations were also in reinforced concrete.

The committee find that the plans and drawings were satisfactorily prepared they call attention, however, to the fact that certain columns on the ground floor were not placed vertically above the columns in the basement, but rested on the beams, which therefore called for special care in construction. The plans had been approved by the local authority, but the committee consider the system of inspection of plans in some ways unsatisfactory, and a revision of this system may become necessary as a consequence of the accident. The contractors, the "Basler Baugesellschaft vorm. Rud. Linder," had previously successfully constructed several buildings on the same system, *i.e.*, Hennebique system. It is stated that there was a want of clearness as to the responsibility of the different engineers and foremen for the work as it proceeded, and in fact the removal of the centering of the ground floor on the day of the accident was contrary to the advice of the engineer having immediate control of the reinforced concrete work.

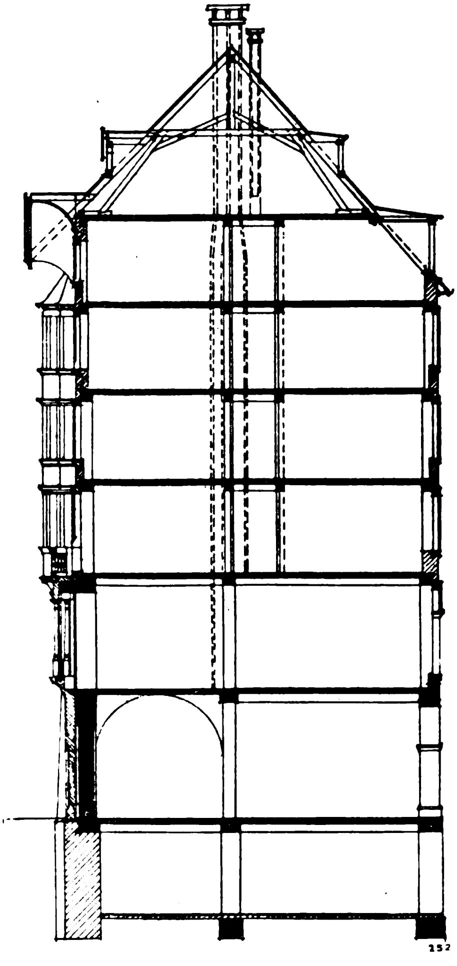


FIG. 3. SECTION

The contract was pushed forward with great haste. The agreement between the builders and the firm of Hennebique in Paris being dated April 20th, 1901, the latter firm, it is stated, was repeatedly pressed for delivery of the plans, the last of which were received in Bâle by July 22nd. The actual reinforced concrete construction was also pressed forward with great rapidity, as is shown in the report by a table giving the progress of the concrete work and of the removal of centering. It is considered that the removal of the supports threw an undue load on the columns before their hardening was complete.

Materials Employed.

The concrete employed was composed of one part of cement and six parts of unwashed ballast. Subsequent tests proved that the cement, a slow-setting Portland cement from Metz, was of good quality, but the concrete prepared from the materials used gave a compressive strength, after 28 days, of only 99 kg./cm.^{2} (1,408 lb. per square inch), or less than half that which would have been obtained with normal materials, namely, 210 k.g. cm.^{2} (2,987 lb. per square inch). This is attributed by the committee to the use of ballast in an unwashed state, the presence of dirt and fine sand having an injurious effect. Cubes cut from the concrete structures of the collapsed building also gave a very low compressive strength, and in several cases showed evidence of insufficient ramming during construction. The compressive strength of the concrete employed was less than that needed to resist the calculated stresses, and this also applies to those portions of the building which remained standing, allowance being made for the increase of strength with age.

Statical Calculations.

The statical calculations, the originals of which were inspected by the committee, were made in the offices of Messrs. Hennebique in Paris. The calculation of the floors was found to be correct, although the committee is of opinion that the Hennebique formula gives too low a value for the stresses produced. In certain cases, moreover, the reinforcing rods were placed too closely together, so that efficient ramming of the concrete was not likely to be secured. In the case of the square columns, the committee's calculations agree well with those of the engineers, but the round column A^1 (*Fig.* 2) is found by them to be 50 per cent. too small, apparently owing to an error of calculation, and the column A is little better.

The accident seems to have commenced by the collapse of the Hennebique beams 3 and 4 over the ground floor, followed immediately by the fall of column A^1 on the first floor (*Figs.* 1, 2 *and* 3). The beams 3 and 4 were not constructed as a continuous beam, but rested on the small brick pillar "*a.*" On the day of the accident, this pillar was being cased in brickwork for the purpose of adding the ornamental brick arches (*Fig.* 5). This involved removing the centering of the beams 3 and 4, which had to carry the entire weight borne by the square pillar B on the first floor vertically above the small pillar "*a.*" A crack was noticed in the beam immediately after the removal of the centering.

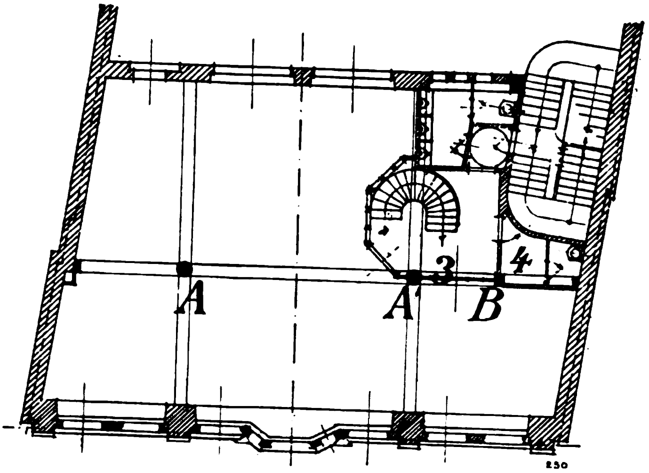


FIG. 2. FIRST FLOOR.

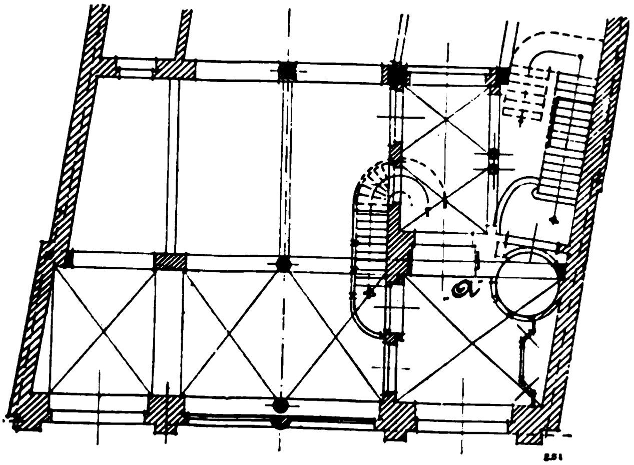


FIG. 1. GROUND FLOOR.
THE PLANS OF THE BUILDING.

Conclusions.

The following are the conclusions of this very exhaustive report:—

The principal cause of the collapse is: The want of care in the removal of the centering from the beams 3 and 4 over the ground floor, and the insufficient support given to them during the bricking-in of the pillar "*a.*"

Contributory causes are:—

(*a*) The inadequate dimensions of the column A^1 on the first floor, together with a general insufficient control of the dimensions by the contractors;

(*b*) The use of a material unsuitable for this form of construction, namely, unwashed ballast;

(*c*) Insufficient care in carrying out the concrete work, especially in ramming;

(*d*) The fact that no tests of the strength of the concrete were made, regardless of the high resistance necessitated by the Hennebique method of calculation;

(*e*) A want of clearness in the organisation of responsibility among the contractor's officials; and

(*f*) The haste in the carrying out of the work, and the unsuitable sequence adopted in removing the centering from the different stories.

Opinions of the Committee.

These conclusions are prefaced by the following opinion, which we translate freely:—

Prior to arriving at the conclusions, the committee have made a point of inquiring whether this accident has any bearing on the Hennebique system as such, and they negative this explaining that except for certain insufficient dimensions of certain individual constructional parts, the accident was mainly brought about by faults in the execution of the work. The committee consider that at the time of writing there was no absolutely clear and generally accepted principle for calculating the stresses and strains in the Hennebique system, but that the various methods of calculation at the time were sufficient for approximately arriving at the facts as to the stability of constructional work. Further, it must be considered that a large number of interesting works have been executed in many lands without there apparently being a greater number of accidents than in work of an ordinary character.

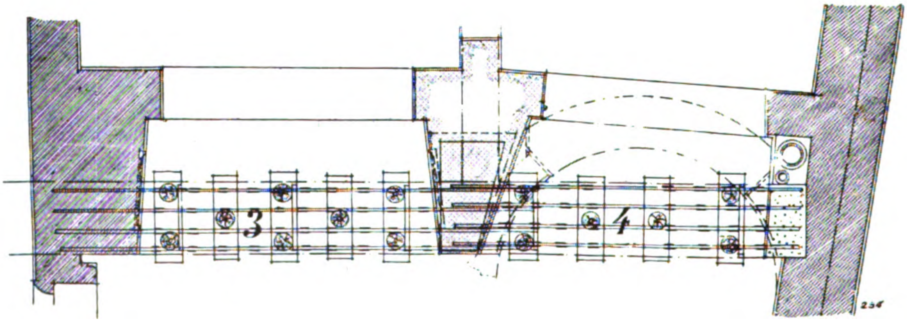


FIG. 4. DETAIL TO GROUND FLOOR PLAN.

The committee indicate that they consider it a matter of congratulation that the accident did not prove any specific fault in the principle of the system of construction.

They further consider that the most useful result of the failure should be a further careful development of the system in question and the application of the greatest possible care in the execution of the work carried out under the system.

Continuing, the committee indicate that although the failure could not be attributed to the Hennebique system as such, they would desire to call attention to the fact that in the application of the system and in the method of its employment, there have been various developments and changes from time to time which tend—at the time of writing the report—towards more daring forms of construction than were applied in earlier years. The committee thus find there is a tendency to find modern forms of construction under the name of Hennebique which differ very materially from what was originally understood under that system, and that it would thus be wise, in future, not only to consider the name under which any special constructional work is put forward, but that every such piece of work should be considered specifically and individually as to design and the calculation of stresses and strains.

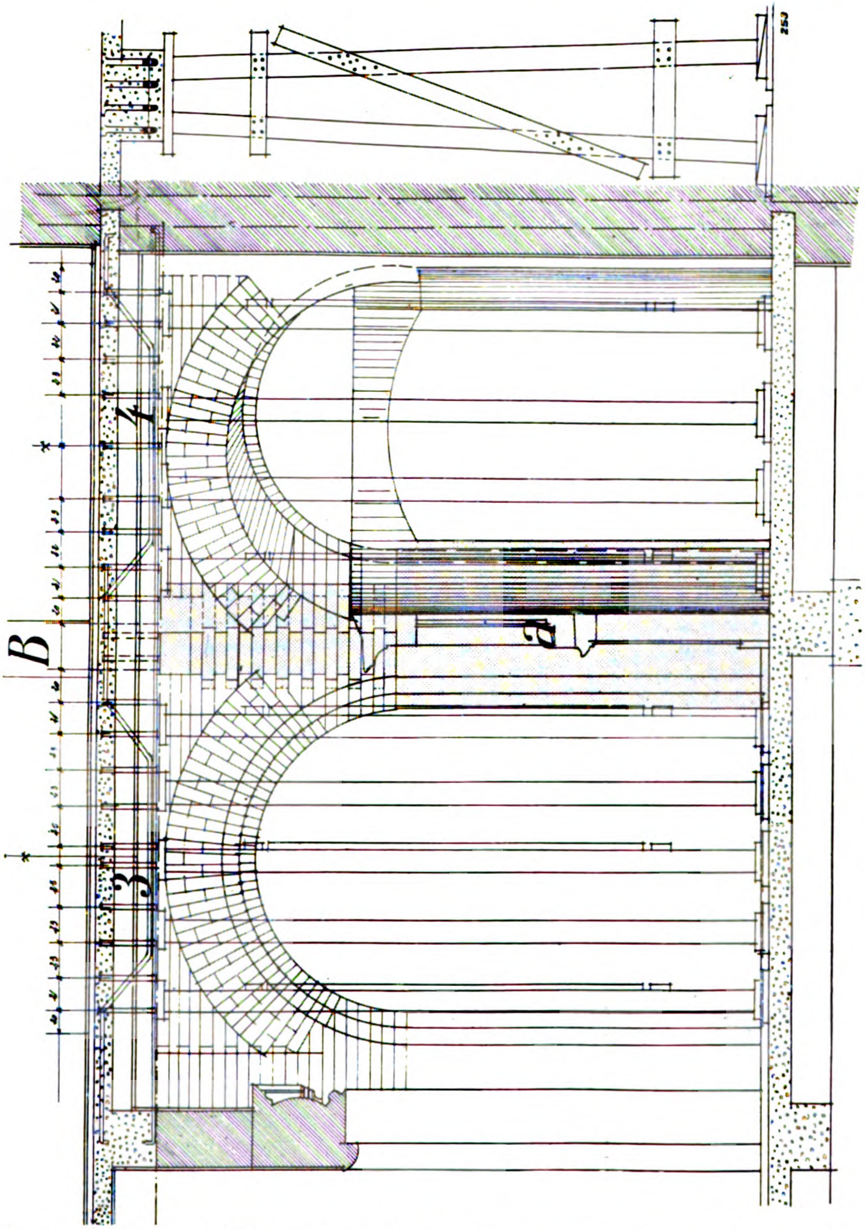
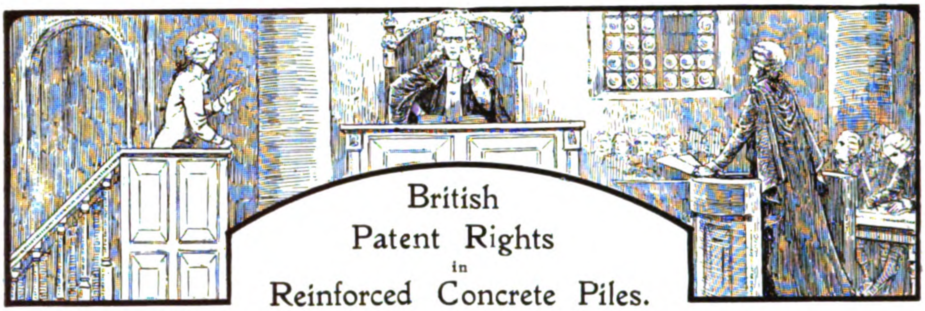


Fig. 5. Detail to Ground Floor Plan.



British Patent Rights in Reinforced Concrete Piles.

MOUCHEL and Another *versus* COIGNET and Others.

By a BARRISTER-AT-LAW.

In a journal of this description important law cases must necessarily be dealt with from time to time. Such a case—recently fought between the representatives of two leading French Reinforced Concrete specialists—relating to the British patents of piles must certainly rank as a remarkable one. For besides being of direct interest to all who hope that no department of reinforced concrete may ever become a monopoly in the British Isles, the findings demonstrate the extraordinary differences existent between British law and what we would term the common-sense of the engineering profession. Reinforced Concrete piles, although admittedly used abroad prior to 1897, are apparently the subject of a bona fide patent in this country issued that year, failing a British anticipation or sufficient publicity in Great Britain. Such anomalies between law and technical opinion are regrettable, and the sooner a remedy can be found, the better for the unfettered development of our industries. Our colonial and foreign readers should, however, note that the case is one regarding British patent rights only, and that the last word has probably not even been spoken on the subject in Great Britain.—ED.

THIS important case occupied the attention of Mr. Justice Warrington for several days near the end of June, and he gave judgment on July 18th. Mr. C. A. Cripps, K.C., Mr. A. J. Walter, and Mr. H. A. Colefax appeared for the plaintiffs; and Mr. J. M. Astbury, K.C., M.P., and Mr. J. C. Graham were for the defendants.

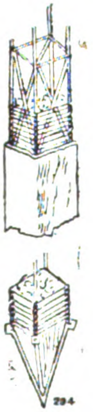
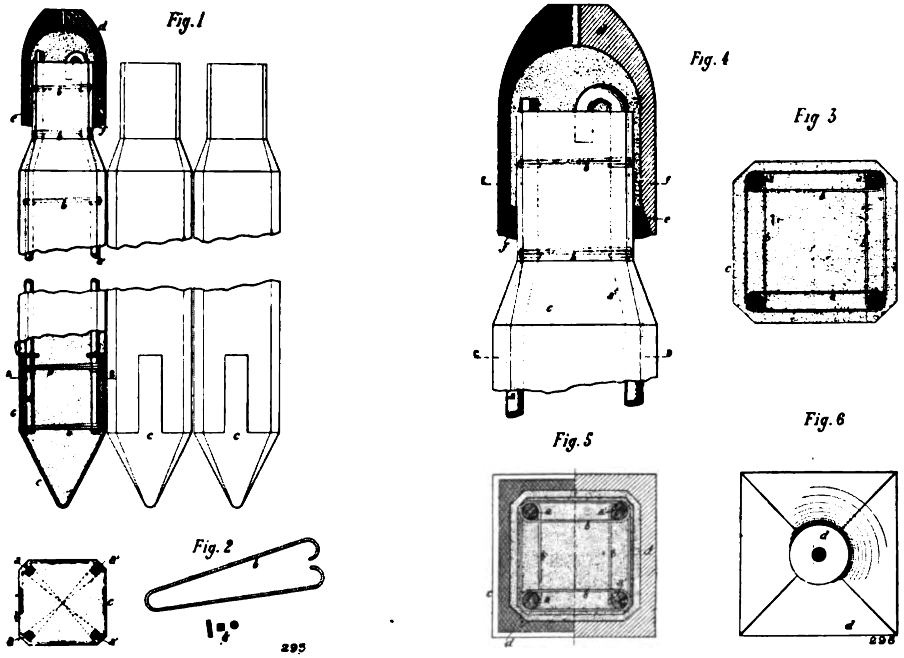


FIG. 10 OF THE BRANNON PATENT, NO. 2703 OF 1871

The plaintiffs alleged that their rights under Hennebique's Patent, No. 10203, of 1897, had been infringed by Messrs. Coignet, Workman and Cowlin and Sons, particularly by the use of certain piles in some works now under construction at Bristol. The defendants denied infringement and also maintained that the patent was bad for want of subject matter, and also because it had been anticipated.

Before proceeding with the evidence, it may be useful to state briefly the law as to anticipation by prior user and prior publication, where acts have been done abroad or descriptions have appeared in foreign publications. In order to constitute anticipation of a British patent there must be either sufficient prior user or sufficient prior publication in this country. Mere user abroad will not invalidate; nor will a description published in this country of an article so used abroad, unless such description is sufficiently explicit to enable the invention to be carried out. The Statute of Monopolies provided *inter alia*, for the granting of letters patent for the sole working or making of any manner of new manufactures "within the realm," to the true and first inventor, which others at the time of making such letters patent should not use. Hence, if an invention be made abroad, the first person who introduces it into this country is entitled to patent it. It was largely with a view to the protection of such imported inventions that the Act was passed. So the mere fact that reinforced concrete piles had been constructed abroad would not anticipate Messrs. Mouchel's subsequent British patents, even though descriptions of the foreign piles had been described by British or Foreign publications in this country, provided the descriptions were not plain and full enough to allow of a competent person constructing the piles without other directions and without invention on his part.



FIGS. 1 TO 6 OF THE HENNEBIQUE PATENT, NO. 10203 OF 1897.

EVIDENCE.

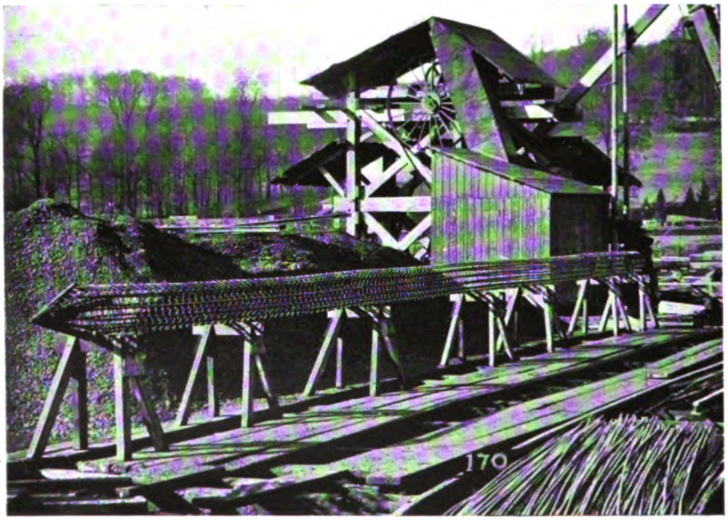
(For the Plaintiffs.)

Mr. Dugald Clerk was the first witness for the plaintiffs. He said he had been to Bristol, and had seen the piles used by the defendants. There was a loose skeleton framework, consisting of longitudinal rods and an encircling spiral wire. The shoe had cast into it bent iron bars which were embedded in the cement clear of the rods. In cross-examination Mr. Clerk admitted that there were certain differences between the driving caps used by the defendants and those claimed by the plaintiff's patent. In his opinion, the invention consisted in firstly, the appreciation of the fact that one could arrange for armoured concrete to be driven as a pile; and, secondly, the construction of a pile to be driven, with all its incidents. Brannon's specification did not show anything that would be called, nowadays, an armoured concrete pile, because the strength of the pile described by him depended on the metallic structure which was firmly bolted together. It could be driven by itself and afterwards heavily rammed with concrete. Assuming that before 1897 it was known that ferro-concrete could be used as a pile, Hennebique's invention would be nothing. He distinguished between the plaintiff's invention and those of Imray 1883, Wilson 1885, Bordenave 1887, Stempel (U.S.) 1889, Edwards 1891, and Hennebique 1892. The reference to Coignet and Coiseau's French and Belgian patents published in this country was insufficient. Merely stating that it was proposed to use ferro-concrete for piles, was not enough, as there was no indication of how it was to be carried out. Though the defendants employed more rods and used a spiral wire, their construction did not really differ from the four rods and separate direct stirrups or cramps of the plaintiffs.

Mr. James Swinburne was of opinion that the Coignet pile took the plaintiff's invention. He did not think the defendants had infringed the plaintiff's cap. He did not find in any of the various specifications cited any anticipation of the plaintiff's invention. Cross-examined, he expressed the opinion that the real principle of Hennebique's invention consisted in the conception that ferro-concrete could be used for piling. An engineer who knew that ferro-concrete could be so used, and who determined to put the idea into practice, would have no difficulty in designing the pile. The particular practical way Hennebique showed was not his invention, it was the way he carried out his invention. A ferro-concrete pile could be hollow.

(For the Defendants.)

For the defendants *Mr. G. C. Marks* testified that ferro-concrete was well known and understood in this country prior to 1897. The defendant's pile was not constructed in any way in accordance with the plaintiffs' specification. Brannon's *Fig.* 10 would be a very good ferro-concrete pile. Anyone looking at it could have no doubt that it could be driven. Wilson's ferro-concrete post could be used as a pile. Bordenave's metal construction was almost identical with the defendants. A pile or post so made and concreted would be a very strong structure. Stempel's construction was ferro-concrete, and if put into the earth with a structure upon it would be a pile. The metal part was practically identical with the plaintiffs'. The conception of using ferro-concrete for piles was published in this country, in 1896, by the reference to Coignet's invention of 1894. Cross-examined: A metallic structure covered with concrete was ferro-concrete if the concrete was doing any useful work and the metal was arranged where it should be. Imray was the first to show that the parts of the frame could be attached together without bolts. The presence of iron in a ferro-concrete pile trebled the ability of the concrete to withstand compression. Once the fact was appreciated that one could drive concrete without shattering the top, there would be no difficulty about the ability of concrete to withstand the compression of the blow. That was the meaning of the plaintiffs' specification.



Piles in Course of Construction at Bristol.

Mr. Francis Fox, M.Inst.C.E., did not consider that the word "pile" indicated something which was necessarily driven by percussion. The true definition of a pile was: A beam of some form or other to which you must apply force in order to get it down in some way or other. Iron had been used in connection with concrete for twenty-five or thirty years, but it had only gradually become called ferro-concrete. The term meant concrete strengthened to meet the tensile strains in the iron, or iron strengthened by means of concrete to meet compression strains. In his opinion, the application to piles of the principles applied by Hennebique to girders in his earlier patent, did not involve invention. With Brannon's *Fig.* 10, and the description of it he could go to work and do it without asking another question. He could make the pile and drive it. He found nothing constructionally defective in it, but for ordinary purposes it was a great deal stronger than necessary. A telegraph-pole made according to Wilson's *Figs.* 23 and 24 would be properly described as ferro-concrete and might be used as a pile. Stempel's gate post was practically the same as the plaintiffs' construction, it could be used either washing it in by the water jet or with the shoe. But Stempel did not contemplate the resistance of any considerable strain. The abridgment of the Belgian patent indicated ferro-concrete piles and in view of that there was no invention in what Hennebique had disclosed in his specification. The plaintiffs' framework by itself acted in a totally different way to that in which it would act when combined with concrete. In cross-examination, he admitted that his partner, Sir Douglas Fox, did not consider ferro-concrete very desirable where it was to be exposed to blows, and had not used ferro-concrete piles at Buenos Ayres. He (the witness) had never used ferro-concrete piles. A very large majority of the piles he had put into position were driven in. He had never tried driving concrete by concussion, and it had never occurred to him that concrete could be so used as to resist the driving concussion strains of a monkey. The iron stanchions in Brannon (*Fig.* 10), probably indicated that they were to bear a large proportion of the driving strain. Generally speaking, concrete was much cheaper than metal. For pile purposes, the ferro-concrete would have to be specially designed according to the work it had to fulfil. His firm were not then using the ferro-concrete piles in any work which it was carrying out.

Mons. Edmond Coignet deposed that he took out Patents in France and Belgium in 1894 for piles in cement with metallic framework. He adopted the design of binding the outside of the rods with the spiral already referred to in the case. The coils were arranged nearer together towards the top to make the pile itself capable of taking the driving strain. He did not use a cap, but just an interposed piece of wood. He was not concerned with the work at Bristol, except as Messrs. Cowlins' licensor. Mr. Workman had only acted as his agent.

His Lordship then adjourned to inspect some of the actual piles which had been brought into the courtyard of the Law Courts.

Mr. Astbury made his speech for the defence, and Mr. Cripps having delivered his reply, his Lordship intimated that he would consider his judgment.

JUDGMENT.

Mr. JUSTICE WARRINGTON: This is an action for the infringment of letters patent No. 10203 of 1897, for improvements in piles, quays, and retaining walls or structures granted to the plaintiff, Francois Hennebique.

The defendants deny infringement, and they raise two defences impugning the validity of the patent, *viz.*, want of sufficient invention and want of novelty. The Particulars of Breaches allege the use of the invention at Bristol. The plaintiffs have failed to prove any infringement by the defendants, Coignet and Workman, and there must, in anycase, be judgment for those two defendants.

The plaintiffs allege that Hennebique invented a new manufacture, that is to say, piles made of strengthened or fortified or armoured concrete (to use three synonymous expressions for describing the same thing) which had never been made before, which are capable of being driven with a monkey in the same way as piles of wood or iron, and which have many advantages over piles of those materials. Neither the utility of the alleged invention nor the fact that the piles made of strengthened concrete were never used in this country before the date of the plaintiff's patent is disputed. The defendants, however, say, and say truly, that strengthened concrete, was in 1897, a well-known material used for many purposes in building, and the plaintiffs' alleged invention is nothing more than the application of the same material to another purpose, and they say that in this there is no invention; and, further, that such application of strengthened concrete has been anticipated by certain earlier specifications, and by the title of a Belgian patent of Monsieur Coignet, published in this country in 1896.

Before considering the specification it is necessary to understand what is meant by "strengthened concrete." I think it may be shortly described as concrete strengthened by the incorporation in it of rods or bars of iron so arranged as to supply the power of resisting tension strains, a power possessed in a marked degree by iron, but hardly at all by concrete, which on the other hand, possesses a great power of resistance to compression strains.

It is further necessary to understand what is meant by a pile. This is a beam or post intended to be placed into position by the application of force. The force may be applied in more ways than one, but by far the most common is by driving, that is to say, by the impact of a heavy weight on the upper end. I find, as a fact, that no pile would be considered by an engineer as effective unless it be capable of being driven. I find also, that until the plaintiffs' patent, although strengthened concrete and its various uses have been familiar to engineers for several years, no one had thought of making a pile of that material, the reason being that it was considered unfit to bear the bursting strain which would be occasioned in driving, and, therefore, that a pile of strengthened concrete would not possess one of the essential features of an efficient pile, that is to say, the capability of being driven. The view I have just expressed is founded not only on the evidence of the plaintiffs' witnesses, but also on that of the defendants' witness, Mr. Fox, who is put forward as an engineer especially skilled in all matters relating to the use of cement or concrete. The fact I have just mentioned is of considerable importance in view of the defence of want of sufficient invention to support the patent.

I now come to the plaintiffs' specification. The inventor says in that document at the commencement:—

> "Beton or concrete strengthened with iron or steel has already been employed in building construction in various ways. Thus more particularly in the formation of girders and beams of strengthened beton there are obtained many advantages, particularly shown by the use of a rational mixture of iron or steel and cement, the former being extremely suitable for resisting the effects of traction or tension, and the latter offering a considerable resistance to stress or compression. A capital point for the construction of a practical girder or beam is to connect the bars of metal

> forming the cord of tension with the cord of compression by means of suitable stirrup pieces and in a former patent of mine, No. 14530, of 1892, I indicated a certain number of improvements which I introduced into these stirrup or cross-pieces, which in this girder made of strengthened beton play the part of the suspension rods of the lattice work of metallic girders, and ensure a perfect resistance of the girder to the severing action under a bending strain. I have applied these principles to the construction of piles, sheet piles, and solid uprights or standards which, corresponding to the special conditions of their arrangements or employment may, according to the strains, the load and the pressures to which they are subjected, be assimilated to girders whether placed on two or more supports or embedded at one end, and so forth. The construction of these piles and sheet piles, their combination and the method of placing them in position, as well as the application of which these separate and combined elements are capable form the object of the present invention."

He thus shows that he is aware of the purposes for which strengthened concrete had been used, and the principles on which its use depended and that he had set himself to construct piles in accordance with those principles, and that the construction of those piles was one of the objects of the invention. He then proceeds to describe the pile by reference to drawings. It is nearly square in section, having rods of iron from end to end within each of the four corners, united by cross pieces of iron of smaller section at certain intervals in their length. The lower part is armed with a shoe to facilitate driving, and such shoe is affixed to the concrete, and does not take any part of its support from the iron with which the concrete is strengthened. The patentee apparently thought that the pile would require some special protection against injury from impact, and therefore devised a particular form of cap for this purpose. It would seem that under the light of subsequent experience, this was an unnecessary precaution. The patentee concludes the descriptive part of the specification in the following words :—

> "The piles and solid sheet piles of strengthened beton which, owing to the arrangement of the protective cap which I have described, may be driven into the ground with the same facility as piles or sheet piles of wood, have numerous advantages over these latter, as not only does the method of moulding and of protecting enable any suitable power of resistance, and any desired forms and dimensions to be given them, but where it is a question of a dam or wall, it may be constructed without interfering with the navigation, and without its being necessary to lower the level of the water. Their non-liability to alter in air or water allows of constructions of this strengthened beton being raised above the level of the water when works erected in timber cannot bear the alterations of dryness and humidity. Foundations of this strengthened beton, as regards economy, facility of execution, maintenance, and repairs, advantageously replace foundations or caissons of compressed air."

Then the material claims are as follows :—

> "Piles formed of bars of iron embedded in beton and cross-tied by cramps in such a way as to always form a solid girder, practically constructed for supporting the weight of an upper building or construction, or any desired lateral horizontal pressures, substantially as hereinbefore described and shown in the accompanying drawings."

And then, leaving out the claim relating to sheet piles, with which we have nothing to do, he goes on with regard to the cap :—

> "In piles of the kind described, a metal cap substantially as hereinbefore described and shown in the accompanying drawings, for use in ramming, enabling the head of the pile or sheet pile to be entirely encased and to distribute the pressure of the blows of the ram uniformly on all the faces of the said head by means of an interposed cushion of sand."

I am of opinion, both on the construction of the specification, and in fact, that the patent is for a new manufacture, namely, a pile capable of being driven and of a particular construction, and of a particular material, and I proceed to consider the several defences on that footing. The questions relate to Claim 1 only, the plaintiffs having failed to prove any infringement of Clause 3.

First, as to the defence of want of subject matter. It is contended that the invention consists merely in the idea of using strengthened concrete for piles, and that this would not support the patent. This, however, is not so. The patent is for the pile, and in the production of this there is, in my opinion, sufficient invention. I am not forgetting that it was said by Mr. Swinburne that, given the conception that armoured concrete could be used for a pile, a competent engineer would have no difficulty in designing one. This may well be so, and yet the resulting product may be good subject matter. It is the result of applying known methods to the carrying into practice of new ideas, and I think for this there can undoubtedly be a valid patent.

Now as to the alleged anticipations. The first is Brannon's specification No. 2703 of 1871. He describes his invention on p. 3 as follows :—

> "My invention has reference to the mode of forming the roofs, tiles, slabs, or flagstones, floors ceilings, stairs, doors, walls, and other parts of buildings or other structures upon the principle which I term monolithic construction of cement, concrete, or concreted earthy or other materials in combination with metallic, fibrous or lamellated substances, with a view to render the said buildings more durable, fire-proof, and healthy, than those of the present construction, and consists in employing for the above purposes a sustaining metallic skeleton or framework firmly bolted or bound together, upon which is stretched open wirework, the whole so arranged as to admit of being

> entirely or partially enclosed or embedded in the said concreted, or other materials, composing the structure, or portions thereof, and thus secure perfect bonding of the same into a solid and coherent mass, and to further increase the coherency and solidity of the mass, and render the same capable of resisting transverse and tensile strains when applied to floors, roofs, arches, bridges, viaducts, and aqueducts, I intimately commingle with the concreted materials upon the principle which I term stone-felting or litho-felting process, and interpose between successive layers thereof or between courses or layers of bricks, tiles, or stones, or any lamellated material, strands or fabrics of wire or fibrous substances, and in the construction of fortifications and retaining walls or embankments, piers, and other marine works to effect the bonding of the mass."

Now, to pause there for one moment, there is no reference in that part of the description to the use of the invention for the purposes of piles. There is no indication in that part, or, so far as I can find in any other part of the specification, of the patentee's familiarity with strengthened concrete. What he is referring to is a sustained metallic skeleton, or framework, firmly bolted or bound together, and then capable of being enclosed or embedded in concrete. Now, the only reference to a pile is in the reference on p. 5 to *Fig.* 10 in the drawings. "*Fig.* 10 shows a mode of forming or constructing pillars or piles with trussed framing and wirework both enclosing and incorporating heavily rammed concrete, the lower section showing the arrangement for marine piling, by bolting the stanchion framing to a shoe." *Fig.* 10 shows a pile of iron framing filled in and coated with cement, and with a shoe forming part of the iron structure. The iron framework is a structure in itself, that is to say, it is, as he describes on p. 3, firmly bolted or bound together.

In my opinion, on the evidence before me, this is not a pile of strengthened concrete at all. I think Mr. Dugald Clerk puts the point most clearly in answer to Question 739 on p. 68. He there says this: "He" (that is Brannon) "does not show anything that would be called nowadays an armoured concrete pile. The armoured concrete pile is a loose metallic structure depending upon the concrete and iron, not a rigid structure. The real cause of the success of armoured concrete is that it does away with all riveted and ironwork joints and ironwork generally, and for a few pounds you can put up iron and steel enough without any riveting whatever," and I accept his view. I think *Fig.* 10 of Brannon was no anticipation.

The other specifications relied upon are all for various applications of iron and concrete, but none of them, in my opinion, suggests a pile capable of being driven with a monkey.

There remains the note of the Belgian patent by Monsieur Coignet, published in 1896. That note is in these terms. It is merely a reference to the title of a patent, which had been taken out in the year 1894, and it is described as an importation from abroad, for piles and sheet piles in cement with a metallic skeleton and then what appears to be, I suppose, the first words of the specification are set out :—

> "The invention has, as its object, a new system of piles and sheet piles of a special construction of such a nature as to render them not subject to the attacks of teredos in submarine works, and in general not subject to the attacks of all those agents of destruction which are found in fresh water, while still giving them the same qualities of resistance to compression and flexion as those of piles and sheet piles of wood."

This tells you that someone had taken out a patent for a pile of cement with metallic skeleton, but there is no information as to the mode of construction. For all that appears, the description, when read, might have involved an engineering failure.

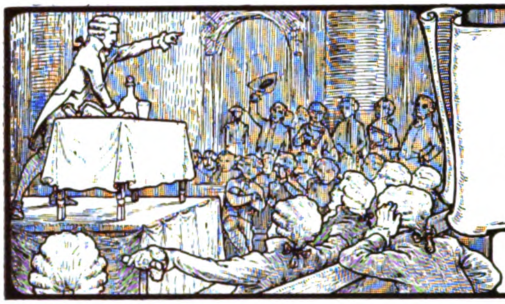
I find, therefore, that there has been no anticipation either by the several specifications which have been referred to, or by the title of Coignet's patent.

The patent being valid, have the plaintiffs proved infringement? The defendants, William Cowlin and Son, have unquestionably used at Bristol piles constructed of strengthened concrete. These piles were provided with a shoe, and the attachments of the shoe were incorporated in the concrete and not bolted, or fixed to any part of the iron. On the other hand, they were cylindrical in shape, and not square like the plaintiffs', and had incorporated in them a larger number of rods than those in the plaintiffs' piles, namely, twelve instead of four, and such rods were connected, not, as in the plaintiffs' pile, by cross pieces of iron at intervals in their length, but by wire running continuously in a spiral coil from one end of the pile to the other, the lines of the spiral approaching more nearly to each other as the head of the pile is reached.

I find, on the evidence, that there is no substantial distinction between the two piles arising from any of the matters I have mentioned, or in any other respect. The defendants' pile is, therefore, in my judgment, an infringement of the plaintiffs' patent.

There must, therefore, be an injunction with damages, or an account of profits, against the defendants Cowlin and Son, so far as regards Claim 1, and they must pay the plaintiffs' costs, except so far as those costs relate to the alleged infringement of Claim 3. The costs relating to that issue must be paid by the plaintiffs with a set-off.

As regards Coignet and Workman, the action must be dismissed against them with costs, so far as they have incurred any costs separate from the defendants Cowlin and Sons. A short stay was allowed in respect of the works at Bristol, pending the plaintiff's decision as to giving notice of appeal.



Reinforced Concrete at the International Congress of Architects, London, 1906.

THE PAPERS AND DISCUSSION.

The following is a special report of the proceedings of a meeting on Reinforced Concrete, held on the occasion of the Congress, with some comments on the arrangement of the Conference generally. Unfortunately, the full text of the papers presented at the Congress were not available at the time of this important gathering, and extracts only of the papers had been issued prior to the discussion.—ED.

THE Seventh International Congress of Architects, which was held in London during July, was well attended, and, in many respects, a most successful gathering, both on the instructive side and as a social event. Its organisation did great credit to Mr. John Belcher, A.R.A., and to the indefatigable secretary, Mr. W. J. Locke, M.A.

As to the improvements at future Congresses of this description, we hold that it is essential that the full papers should be printed in advance and distributed, as has long been the practice at Engineering Conferences. It seemed somewhat extraordinary that papers which, as a matter of fact, for the most part were in type, were not available prior to the meetings. The extracts issued were almost valueless.

Another improvement we would propose is the rigid censoring of papers and rejection of unsuitable ones. One author in particular who contributed nearly a dozen "papers" should have been "gagged." A notorious trade "paper" should also not have found a place on the Congress programme.

At any future Congress of Architects, if held in Great Britain, it would also be advisable that some effort be made that the Government be officially represented on an occasion of this kind. We think we are not mistaken in saying that the Government and the various Departments have been occasionally represented officially at other technical Congresses. It does not add to the dignity of the architectural profession if, during the whole proceedings of a week, H.M. Government could not apparently be officially represented on one single occasion.

Socially, at future gatherings we should like to have seen more attention paid to our Colonial visitors. Congress members from the Continent were acclaimed and accorded many courtesies. The Colonials unfortunately stood absolutely in the background, and we cannot recollect a single Colonial being called upon to speak even on such festive occasions as the opening at the Guildhall and the farewell banquet.

And now one other hint on the social side. Englishmen, whenever visiting the Continent of Europe are not only accorded much official hospitality but much private hospitality. We observed with great regret that private hospitality accorded by the British architect to the Colonial or Foreign *confrère* was quite the exception.

As to the papers at the Congress and the technical discussions, there was much of an instructive character, and it was only regrettable that as a rule the actual "reading" of the papers occupied too much time in comparison with the time available for discussion. The procedure of the Engineering Societies of printing the papers in full, only allowing a short five minutes for the introduction of the author of the paper and then immediately commencing the discussion is preferable. Occasionally time might be accorded to an address illustrated by lantern slides, such as Herr Stübben's on the laying out of cities, but this should be very much the exception.

CONSTRUCTIONAL ASPECTS OF ARCHITECTURE.

The constructional aspects of architecture did not occupy quite the position that might have been accorded them, having regard to the ever-growing tendency of the public to require great constructional knowledge of architects, and we think this tendency in the direction of science and construction has not yet been quite realised by the senior members of the British profession. Thus, Sir William Emerson at the farewell banquet, in describing the subject matter of the Congress, as a very last item mentioned that *even* Reinforced Concrete had been a subject under review.

Now, reinforced concrete happens to involve most serious problems for the architect of the day, and unless he realises this, as indicated elsewhere, the architect must lose a great deal of the structural work of a practical character which should preferably remain within his professional sphere.

How reinforced concrete occupies the minds of a certain section of the architectural profession can be gauged from the fact that of the three hours devoted to a meeting on "Steel Construction and Reinforced Concrete" according to the programme, steel construction was scarcely mentioned, if at all, and the whole time was occupied by matters appertaining to reinforced concrete. This by no means indicates any lack of appreciation of the importance of the development of steel-frame building, which must be developed parallel and simultaneously with reinforced concrete work, but it indicates that the problems of steel construction have practically been solved, whilst those of reinforced concrete are very much under consideration.

SUMMARY OF THE DISCUSSION.

As to the general trend of the discussion on reinforced concrete and the papers presented, we think that the points which may be said to have been accorded primary attention are those of the architectural rendering of a reinforced concrete building from the artistic point of view ; those as to the necessity of appreciating the causes of failure in reinforced concrete ; and those relating to the necessity of reinforced concrete only being assumed to be fire resisting when certain precautions are observed.

As to the art side, it is really a matter of congratulation that this should have been boldly put forward. The reinforced concrete building has opened up an entirely new vista in architectural life and it is for the architect to seriously consider how reinforced concrete shall be rendered pleasing to the eye.

As to the failures with reinforced concrete, it is only too true that accidents are glossed over and every possible effort made to prevent their being accorded publicity. We, as advocates of concrete and reinforced concrete construction, necessarily are not pleased to hear of accidents with this material, but surely it would be unwise and impolitic to allow the lessons of such accidents not to be properly appreciated, and in order to appreciate the lessons properly it is necessary to give facts, chapter and verse. It is only natural that with reinforced concrete construction—as with other forms of construction—accidents will occur, and what we must try to elucidate is whether such accidents are merely due to neglect or bad workmanship, or if there is anything radically wrong in any system of design employed. We shall hear, as we have already heard, from enthusiasts in reinforced concrete and also from specialist contractors, that the recording of accidents might deter the advancement of reinforced concrete in this country. We are, however, of a different opinion, for we are so convinced that as a rule such accidents are merely due to neglect on the works, bad material or bad workmanship, that it is essential that we should point out where the fault lies, and show that as a rule it is not the system or design, but sheer carelessness that occasions a failure. Further, where there is any fault from the system such faults will show where the system can be improved, and all can only be desirous of such improvements being effected. We congratulate Mr. Max Clarke, F.R.I.B.A., on boldly bringing forward a resolution to the effect that such failures should be investigated, and we hope that the resolution as adopted by the Congress will be acted upon.

As to the fire resistance of reinforced concrete, we have already indicated our views which are, perhaps, best expressed as being identical with those of the Fire Congress at Milan which practically stated that reinforced concrete could only be regarded as a fire resistant if composed of a suitable aggregate and if all steel parts be well protected against the impingement of flame. These elementary essentials as to the fire resistance of concrete have unfortunately not yet been properly appreciated by the vast majority of those who employ reinforced concrete. The fact that reinforced concrete comprises incombustible materials is considered to be sufficient to prove its fire resistance. This is obviously wrong, and the sooner that the general public, the building employer, the local authority, and, above all, the architect and engineer, will realise that reinforced concrete is only fire resisting when steel bars are properly protected by a suitable concrete aggregate, the better for the community at large.

THE PAPERS AND THE DISCUSSION.

As to the papers and the discussion, of course in a Journal of this description, appearing several weeks after the Conference, a recapitulation of much that has appeared in our architectural weekly contemporaries may not seem in place. Yet in many cases those journals do not reach the eye of the engineer, and we thus hold that the current issue would be incomplete without a *resumé*. Thus we present a summary with headings, with a view of facilitating reference.

Steel and Reinforced Concrete Construction.

At the Seventh International Congress of Architects the subject of "Steel and Reinforced Concrete Construction" was discussed. The meeting took place on Tuesday morning, July 17th.

Mr. Frank Miles Day (President of the American Institute of Architects) presided.

The Chairman, after some preliminary explanations as to the method of procedure, said the subject for discussion was one of life interest. He considered the subject of reinforced concrete was one which appealed to the architect from many points of view, whether it be from the economic view, the purely constructional view, or the yet more difficult one of giving appropriate expression to the material.

The "Reinforced Concrete Committee."

Mr. Searles-Wood, F.R.I.B.A (London), thereupon read a communication from the Reinforced Concrete Committee of the Royal Institute of British Architects, of which the following is an extract :—

The great and increasing use of reinforced concrete in buildings and other structures, and the need of having some authoritative pronouncement on the proper conditions of its use, has led the Royal Institute of British Architects, with the co-operation of other bodies, to appoint a committee to inquire into the subject.

The members of the committee are as follows :—

Nominated by the Royal Institute of British Architects: Sir Henry Tanner, H.M. Office of Works; Professor W. C. Unwin, LL.D., F.R.S.; Charles F. Marsh, M.Inst.C.E.; A. T. Walmisley, M.Inst.C.E.; Max Clarke, F.R.I.B.A.; William Dunn, F.R.I.B.A.; H. D. Searles-Wood, F.R.I.B.A., Colonel F. Winn, late R.E.

Nominated by the War Office.—Colonel C. B. Mayne, R.E.; Major E. M. Paul, R.E.

Nominated by the Incorporated Association of Municipal and County Engineers.—A. E. Collins, M.Inst.C.E.; S. S. Platt, M.Inst.C.E.

Nominated by the District Surveyors' Association.—E. Dru Drury, F.R.I.B.A.; T. H. Watson, F.R.I.B.A.

Nominated by the Institute of Builders.—Benjamin I. Greenwood; Frank May, J.P.

The Committee has appointed Sir Henry Tanner as Chairman, Professor Unwin and Colonel Mayne as vice-chairmen, and Mr. H. D. Searles-Wood as hon. secretary.

It has appeared desirable to the Royal Institute that some statement be made before the International Congress of Architects in London as to the general scope and aim of the Committee, and the following outline is made with their approval.

The aim of the committee's deliberations is to prepare a report, stating their recommendations and conclusions as to :—

1. What drawings and details should be prepared before work is commenced.

2. The nature of the materials which may be employed, and the standards to which these should comply — *i.e.*; (*a*) The metal in reinforcement, (*b*) the matrix, (*c*) the sand, (*d*) the gravel, stone, clinker, or other aggregate, and (*e*) water.

3. What are the proportions for concrete to be used in different cases.

4. How the ingredients for concrete are to be mixed and deposited on the work.

5. The distances to be allowed between the

reinforcing bars and what covering of concrete is necessary.

6. What precautions are necessary in the design and erection of centering and false work, and how long the whole or portions of centering and false work should remain in position.

7. The rules which should be used in determining the dimensions of the several parts necessary for security, and what safe stresses should be allowed.

8. The supervision necessary and the special matters to which it should be directed.

9. The fire-resisting properties of reinforced concrete.

10. Its adaptability for structures where resistance to liquid pressure is essential, and what special precautions may be advisable under these conditions.

11. What are the necessary conditions for its permanence, resistance to rusting of metal, disintegration of concrete or effects of vibration.

12. The testing of materials employed and of the finished structures.

13. What provisions are desirable in Building Laws or Government regulations relating to buildings and other structures so far as these affect the use of reinforced concrete.

The committee having been recently constituted, and only two meetings having been held, no conclusions have been arrived at, and members of the Congress are invited to send communications.

No discussion having followed this communication, *Mr. Goodrich, M.Am.Soc.C.E. (U.S.A.)*, Engineer to the Bush Terminal Company of U.S.A., presented a paper on "Reinforced Concrete and its Relation to Fire Protection." The following are some of the main points of this paper:—

Fire Resistance.

In choosing the subject of "Reinforced Concrete and its Relation to Fire Protection," the writer had in mind the dual conditions necessary to the greatest immunity from fire in large building constructions, particularly where such has varied types of occupancy together with correspondingly different manufacturing fire hazards.

The requisites are, first, the employment of the most incombustible materials and the assembling of these elements in such manner as will most effectively limit the spread of fire; secondly, the equipment of the building with such protective and extinguishing apparatus as a wide experience has determined most effective. Either of these essentials alone will accomplish a large measure of results, but to secure a maximum the combination is necessary.

An exemplification of such a combination is the tenant factory community being developed by the Bush Terminal Company of Brooklyn, N.Y., U.S.A., for which reinforced concrete has been adopted as the structural part of all buildings. These factories were especially designed to take advantage of all insurance regulations, and thus secure the minimum insurance rates on buildings and contents.

Associations of insurance companies in the United States have had the effect of standardising requirements. All the most important points thus developed were carefully considered in the design of the Bush Factories, which thus were provided with: Special fire walls, special stair and elevator shafts, waterproof floors, automatic fire doors, a complete sprinkler equipment, windows of wire glass.

The reinforced concrete design was prepared with special care as to the fire-resisting qualities of the structure. A "unit" system of reinforcement was devised, which proved effective and economical, not liable to derangement during construction, and especially advantageous because allowing of the use of special fire-resisting materials at points of greatest danger. The columns, even though built of concrete, were fireproofed with cinder concrete shells, which served at the same time as a vehicle for the steel reinforcement and as a mould for the construction of the main body of the column.

The building now completed enjoys the lowest rate of fire insurance, both as to structure and contents, accorded any similar risk.

"Clinker," "Cinder," and "Coke Breeze" and the Size of Aggregates.

Mr. Edwin O. Sachs, F.R.S.Ed. (Chairman of the British Fire Prevention Committee), thereupon opened the discussion by asking some questions as follows:—

In the course of Mr. Goodrich's paper the word "cinder" has been used constantly—I would like to know the definition of "cinder" in the United States. Does this term come within the term "coke breeze," as used in this country, or is "cinder" the equivalent of "clinker"?

Mr. Goodrich: "Clinker" is the more synonymous word.

Mr. Sachs: Reference has been made to the fact that the American fire insurance companies' regulations specify the aggregate which has to be used. We hear constantly of "rock" and "stone" aggregates, but there have been experiments showing that "clinker" aggregates and "slag" aggregates seem to have a far higher fire resistance than "rock" or "stone" aggregates.

Mr. Goodrich: The experiments in the United States, as in this country, show that "clinker" and "coke" breeze have a higher fire resistance, but the companies do not discriminate as they should.

Mr. Sachs: Is the size of the aggregate defined in the States? The British fire office regulations require, that every part of the aggregate should pass a 1 in. mesh. Such a precautionary measure is of the utmost importance, as we find in fire tests, and at actual fires that concrete of large aggregate splits and large pieces fall off, with the result that the metal is soon laid bare.

Mr. Goodrich: The American rules do not define the aggregate except that it should be able to pass between the bars, and in no case be larger than 2½ in.

Mr. Sachs having completed his questions thereupon made the following statement: It is to my mind of primary importance, so far as the fire resistance of reinforced concrete is concerned that the protection of all metal-work against the impingement of flame should be perfect. The metal work should be protected by a certain number of inches of concrete of suitable aggregate. The number of inches cannot be exactly defined in the present state of investigation, but the dimension should certainly be 2 in. or more. I would say, however, that it is of equal importance, on this question of the thickness of the protecting covering, that the aggregate should be most carefully defined. Further, as a minor safeguard, I should always recommend the rounding off of all external angles. I offer these three points as being very important ones in relation to fire protection and reinforced concrete.

Mr. Max Clarke, F.R.I.B.A. (Vice-Chairman of the R.I.B.A. Science Committee), then asked the reader of the paper to give a definition for "clinker." Mr. Goodrich had told the meeting that "clinker" and "cinder" were identical, but the meeting desired, he thought, a hard and fast definition of "clinker."

Mr. Clarke went on to say as follows: I think the material to form the aggregate of concrete is one of the subjects which is going to be considered by the Reinforced Concrete Committee, and to me it appears that very serious investigation on the point is needed, and it cannot be too thorough, for it is now fairly well known, from the experiments conducted by the British Fire Prevention Committee, that light and porous materials are generally the best in case of the outbreak of fire, but not the most satisfactory for strength-giving in construction. For the latter purpose most people admit that gravel would be used from choice, but it is almost the worst from a fire point of view. Whether some happy combination can be thought of remains to be evolved from the deliberations of those who have the matter in hand, and I would ask the speaker whether such combinations have been worked out at all in America. The Fire Offices' Committee in London except coke breeze from their list of materials for the aggregate of reinforced concrete, and I understand the regulations of New York are on the same lines. It is not used as one of the materials, but "cinder" is. I would like the reader of the paper to give a hard and fast definition as to what "coke breeze" is contrasted with "clinker." With regard to "coke breeze," I know the Fire Offices' Committee object to it on account of its having a small proportion of unburned coal in it, but, as a matter of fact, the Fire Prevention Committee have shown that unburned coal in the concrete, subjected to a fire of 1800 deg. F. for three hours, comes out of such a fire just as it was put in.

Mr. Goodrich: The definitions differ. We try to exclude materials which are poor. Some engineers allow soft bituminous coal ash or "clinker" to be used. Others require the use only of anthracite material. My personal opinion is that anthracite only should be used. In some cases I have required screening and washing of materials so as to exclude he fine material which would be nothing more than sand of poor quality, and which would simply serve to bring the cement into a hard material which would take the place primarily of gravel, except that it is more porous. It is almost impossible to exclude unburned coal, and in some cases where tests have been made the unburned coal is 50 per cent. of the "clinker," and this was found to be very little affected, except on the surface which is nearest to the fire. The use of 2 in. or 3 in. of covering is well where it can be done, but it seems unnecessary in many cases especially with small material. In any case, the use of a certain amount of unburned coal is almost necessary, and, in all probability, is not detrimental. Whenever the American "unit" system of reinforced concrete is employed, if it is thought worth while, the lower portion of the aggregate could be made of fine material. We all look to the time when the upper part of a reinforced concrete beam can be safely made of rock aggregate and the lower portion of a "cinder" aggregate. Such a combination has actually already been used in some cases and I, myself, have made such a trial beam, before it was suggested in a paper before the American Society of Engineers.

Mr. A. A. Rey (Paris) wished to know to what temperature the experiments had been carried in America in respect to the "unit" system referred to. He also desired to learn to what extent reinforced concrete has been applied to the economical construction of large artisan's dwellings.

Impending Inquiry in the United States.

M. George B. Post (architect, U.S.A.): It may be of interest to know that those in large practice as architects in the United States use reinforced concrete with considerable trepidation from the fact that there are no definitely established constants which can be employed in computing the strains. We are also in constant fear that the concrete is not properly mixed, and that the ingredients are not as perfect as they should be. Thus, our opinion of reinforced concrete is very much like that of the distinguished Mr. Weller with regard to veal pies, *i.e.*, "werry good things when you know'd the lady as made them." We still have to rely on the specialist contractor. We thus all look to the time when we shall know more definite data with regard to the subject. Now to overcome this difficulty as to the absence of sufficient data I have pleasure in reporting that an advisory board* has been instructed to make extensive tests with reinforced concrete and will receive the support of the Federal Governments. Thus I hope that before the next Congress assembles, America will be able to furnish us with valuable information with regard to the whole subject. There is one other point which is to have most careful and thorough investigation, and that is the question as to whether cement is or is not an efficient protection of steel from corrosion. Another matter which I think should receive attention, is the dangers of electrolysis from the huge free current of electricity in all our great cities.

Mr. Goodrich hereupon replying to *M. Rey* stated that the actual temperatures at conflagrations appeared to vary between 1,400 deg. and 2,000 deg F. For tests the temperature required is generally 1700 deg. to 1,800 deg. F., for a period of several hours. As to whether the methods of construction referred to are applied to working class dwellings, the speaker could give no examples.

Professor Louis Cloquet (Central Society of Architecture of Belgium) then read a paper on:—

The Æsthetic Point of View.

We have in mind three kinds of form: those of *convenience*, of *structure*, and of *expression*.

The forms of convenience, by which the building receives its complete usefulness and a character in harmony with its destination, satisfies the mind without causing pleasure to the eye. Those forms of convenience which are, if not the most pleasing, at least the most excellent can be carried out to perfection by making use of the processes, so eminently practical, of reinforced concrete. The forms of expression are those by which the architect and his assistants put their imagination and their soul into the building, in order to impart to it the eloquence of a pleasant aspect. The ideal is that they shall form an integral and inseparable part of the structures. In the buildings constructed of reinforced concrete there is little scope for the artists' talent, especially the sculptor's. There remains hardly anything except the superficial decoration by painting and some polychromic, ceramic, or other adornments, but for the artists in colour a vast field is opened for their creations.

The forms of structure, either real or fictitious, are the principal ornament of the buildings produced by the old methods. They are those organic forms which give life to the aspect of buildings with walls of marked out stones.

In the old-fashioned conception a building is to be compared with a living organism where we can distinguish a skeleton, various members, and a sort of muscular system. Reinforced concrete does not afford these elements of interest and charm; it leaves the impression that the work has been carried out in too docile a material, on which the sacred labour of the workman and his traditional processes have not left the traces of the noble struggle between the artisan and matter. We do not find the same beauty in this work all cast in one block in a dead and dull-coloured material, without organism, with which the best thing that can be done is to hide them beneath a superficial decoration.

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* See page 139 of the second issue.

In conclusion, the new processes, economic and powerful as they are, are precious from the point of view of certain bold and complex accomplishments. They are devoid of the charm of an artistic expression. Besides, economy is only a relative law and of a secondary character, and the boldness of the structure is not always required. A process which is prevalent from these two points of view does not impose itself to the exclusion of the others. Recourse may be had to it for the economic satisfaction of utilitarian projects, for the realisation of comfort, and for the solution of bold problems. But it will never eliminate from architectural practice the noble and artistic combinations of masonry work in marked-out stones, moulded, and sculptured, of frameworks in wood and in metal, etc.

Mr. Gaston Trélat (Paris) then followed with a paper entitled:—

The Advent of Reinforced Concrete.

To sum up, steel and reinforced cement are destined to see their use become general. They are fit to be easily and conveniently used together with other materials such as burnt clay and, above all, sandstone; and in this way can be formed a substantial body provided with solidity and of a nature to assure beauty, a quality not to be neglected.

Moreover, the walls built by this method are excellent with regard to the health of the inhabitants as offering no harbourage to disease germs, against which an incessant war must be waged.

The advantages of this particularly healthy kind of installation are, above all, to be appreciated when it is a question of buildings to be used as hospitals, workhouses, or as cheap lodging-houses.

Steel and reinforced concrete are materials with which it is possible to erect very high buildings and at the same time to reduce the thickness of the parts, such as walls and floors.

From the plastic point of view they can form a body pleasing to the eye.

Architectural Treatment.

Mr. Sachs, in opening the discussion on the two preceding papers, said: Both papers have brought out a point which is of the utmost importance to us as architects if we are going to keep the building of reinforced concrete structures in our own hands, namely the question of the effect of these buildings upon the public. Reinforced concrete buildings at the present moment are being utilised mainly for the very utilitarian purposes of the factory and warehouse, but if the material is to be used in the main thoroughfares of our cities it must be dealt with from the architectural point of view—in other words such buildings must be suitably clothed. The problem is, how to deal with these large flat surfaces, which must necessarily form a reinforced concrete building, and anything which can be done to bring suitable solutions to this problem before architects in the future will be most valuable to the profession, because a suitable solution to the problem will assist architects to retain the design of buildings of this material in their own hands, instead of such buildings being erected by the engineers.

Mr. Francis E. Harris (Manchester): Having been instrumental in putting up a few ferro-concrete buildings in this country, it has been frequently asked me what are the qualities of the external walls in relation to non-conductibility. If we are to use reinforced concrete for any purpose other than manufacturing buildings, we would wish to know, amongst other things, whether the walls are good non-conductors. Our colleagues from abroad who have used reinforced concrete for domestic buildings, will perhaps be able to tell us their experience in this connection. As to architectural effect, my view is that we should simply use concrete for walls and floors. There is a flatness about armoured concrete which would be objectionable unless we use an excessive amount of material, which, of course, will not be an economical thing to do. I would personally like to have an expression of opinion from our continental visitors on two points: (1) As to the qualities of ferro-concrete walls for resisting heat and cold, and (2) whether they found they got a good architectural effect, not merely by decorating the outside of the surface, and if so, could they get it economically?

Mr. Edward P. Warren (London): I would like to introduce a second question with regard to the possibilities of architectural effect. It seems to me that if we are to deal with plain surfaces in which construction in the architectural sense is absent, we must resort to some merely plastic form of decoration or applied decoration. To be honest, in dealing with this form of construction, I would like to ask those who have considered the use of the material whether any serious attempt has been made to give it a real constructive or architectural expression, because if there is no constructive or architectural expression in the building, it is not architecture at all. There can be no architectural inspiration, and no architectural enthusiasm can be aroused by dealing with a structure in which we cannot give any external expression whatever, and in which no constructive problem arises.

Professor Cloquet then answered questions brought forward in regard to the architectural treatment of reinforced concrete wall surfaces by reading passages from his paper dealing with the æsthetic point of view, and which the exigencies of time limit prevented him reading in the first instance. He considered that it would be a great mistake to place anything on the face of the building which was not part of the structure.

With regard to the conductibility of the wall, he found it well to design walls in two thicknesses with a closed air space in between. Reinforced concrete had, he stated, only so far been used on the Continent for domestic purposes to a very moderate extent.

The Economy of Reinforced Concrete.

A paper by Mr. J. Bassegoda (Barcelona) and one by Professor Henry Adams, M.Inst.C.E., were taken as read. *Mr. Bassegoda* indicated:—

Economy in the use of reinforced concrete does not depend on the low price of the materials of which it is composed, which are comparatively dear, but on their accurate combination, which allows of the quantity being reduced. Economy consequently has a limit in the maximum coefficient of ironwork and concrete.

There is no reason why these coefficients, especially that of the concrete, should be higher than in homogeneous construction, for there are many circumstances, all difficult to foresee, which may produce lower resistances than those which have served as a basis in the calculation; such as the quality of the cement, the nature and size of the sand and gravel, and the manipulation of the materials.

This consideration has produced various systems from which the cement has been almost completely eliminated, or in which, at all events, it has not been taken into consideration in the calculation ; it is then considered as a simple binding material destined at the same time to protect the metal against agents which would tend to destroy it, such as oxidation.

Security reaches its maximum in some of these systems, but on the other hand economy diminishes ; in fact, it may happen that this kind of construction may become less economical than other homogeneous kinds, such, for example, as brick laid with cement.

In countries where they have excellent brick which, according to an already old-established custom, they use in very reduced thicknesses, either in the parts which give support or in the parts which are supported (arches and horizontal floorings), one might introduce the system of fortifying these constructions, thus obtaining a greater economy in homogeneous brickwork.

In places where construction in brick does not meet the conditions required, the use of reinforced concrete offers a real and effective economy over all other systems of construction : but an economy which should not be exaggerated whilst admitting coefficients of work very superior to those which experience found to be absolutely safe.

With regard to the artistic point of view of the question, reinforced concrete has no exclusive form ; on the contrary, like every concretion, it takes that which is given to it. The supporting element covering an empty space may be straight (beam) or curved (arch) ; the length of the former is comparatively restricted ; the length of the latter can be much extended, as is also the case in homogeneous constructions.

In the straight form, as in the curved, the theoretical limit of reinforced concrete requires, on account of the weight of the concrete itself, the use of a greater volume of iron in the ironwork than is required in homogeneous metallic constructions. The relation or proportion between the units of resistance and of weight is thirteen times greater in cement than in iron. It follows that in proportion as the absolute dimensions of the works in reinforced concrete are increased, so must the importance of the iron over the cement be increased also, and in consequence the forms that have the characteristics of metallic constructions, as may be noticed in the large bridges.

On the other hand, in architectonic works, in which it is scarcely ever desired to attain the maximum of possible dimensions, the artistic character must come from the lines, projections, and colouration. With regard to the first the architect can freely choose without any restriction ; the second whatever they may be—mouldings, ornamental decorations, etc.—can also be obtained with ease and comparative economy, but with the drawback that for their execution one must have recourse to moulding, which indicates a limitation of artistic effect to which architectonic art cannot bring itself. With regard to colour one cannot admit the only one, that of cement ; but, on the contrary, this modern concrete must be treated as the ancients treated it, that is to say, by covering it either altogether or in part with other materials of which the varied coloration permits of obtaining the desired effect being obtained, as certain architects and engineers are already doing, who have succeeded in using it with a particularly artistic effect.

The Theory of Reinforced Concrete.

Mr. Henry Adams, M.Inst.C.E., indicated :—

So much has been written during the last four or five years upon the use of concrete and steel in combination that there is practically nothing new to be said. Those who have studied the literature of the subject will probably have been struck with the number of different terms used to express this mode of construction. "Béton armé," and the English equivalent, "armoured concrete," are perhaps the least appropriate. "Reinforced concrete" gives undue prominence to one element to the total exclusion of the other ; concrete-steel" is less open to objection, but the writer prefers the term "ferro-concrete" as being self-explanatory of the intimate combination between the two materials, the more important one coming first. A superficial criticism might allege that *ferrum* is iron, and therefore not applicable to steel, but steel is generically iron, and term appropriate.

In early designs no provision whatever was made to resist the shearing stresses, which were either overlooked or ignored, and it is interesting to observe the gradual recognition these stresses obtained in the hands of the designers, until in recent construction they receive nearly as much consideration as what are called the "direct" stresses of tension and compression. The importance of considering shear was brought prominently under notice by the failure of experimental beams which had no special provision for meeting the shear stress towards the ends, where of course it is greatest. Various methods are employed in the different systems, but the Kahn trussed bar seems peculiarly suitable, the fin on either side of the core being left attached throughout the middle portion where the tension is greatest, and separated and bent upwards towards the ends to take shear where tension is least.

The question of adhesion between the concrete and the steel at one time caused some anxiety. It was naturally supposed that with increase of temperature the steel would expand more than the concretet and it was thought that this would be sufficien, to impair, if not to destroy, any adhesion that might be otherwise obtainable. As a matter of fact the linear change for a given variation of temperature is about 15 per cent. less for concrete than for steel, but when the actual figures are compared the difference is very trifling. Taking the range of temperature between summer and winter as 70 deg. F., the change of length in 100 ft. produced by this variation of temperature will be for steel 0·546 in. and for concrete 0·464 in., the difference between the two materials in a length of one foot being less than a thousandth of an inch.

With equal care in mixing the concrete the adhesion varies with the condition of the surface of the steel. When coated with red oxide paint it is extremely slight, and even a bituminous paint reduces the adhesion below that due to a clean unprepared surface. It is, however, found that the best adhesion occurs when the steel is rusted all over before being embedded in the concrete. This appears to be due to the formation of some chemical compound, or salt of iron and lime, which may not be detrimental in the absence of further moisture, but the final result is doubtful in such cases as reservoir walls, tanks and dams. Painting the steelwork over with cement wash is a simple method of commencing the contact.

Professor Bauschinger found the ultimate adhesion to be from 569 lb. to 668 lb. per square inch, but Mr. J. S. Costigan found it not to exceed 65 lb. per square inch. Probably in the former case it was measured by the resistance of a rod to withdrawal, and in the latter by the insertion of small plates in a briquette. At any rate it is not safe to reckon upon more than 50 lb. per square inch as a working load for adhesion. Allowing 16,000 lb. per square inch as the working load on steel, the embedded length that would make the strength and adhesion equal would be 16,000 times the sectional area of steel in square inches divided by fifty times the surface area per inch in length, or briefly 320 $a \div s$; so that a quarter-inch square bar embedded for a length of twenty inches would be equally strong against tearing or slipping. and similarly a 1-inch square bar would need to be embedded for a length of 80 in. There are many different constructions in which this fact may be of importance; for instance, in a simple beam, if the span is less than twice the above lengths, there will be a tendency for the rod to draw before the tensile strength is utilised, unless the ends are turned up to form cleats. In the edge of a circular ferro-concrete tank, instead of overlapping the ends of the rods, for which the above distance would be a minimum, it would clearly be more economical to turn up the ends and slip a welded link over them. There are several specially prepared bars giving greater resistance to withdrawal, *e.g.* the Ransome twisted bar, the square corrugated bar, and the Columbian bar, which rely for efficiency upon large surface area compared with sectional area.

Ferro-concrete does not at first sight lend itself readily to architectural effect; the warehouses and coal stores constructed of it can hardly be called visions of beauty, but some of the recent arched bridges have a decidedly pleasing effect, and when the adaptability of the compound material becomes better known we may confidently look forward to the expression of taste as well as utility in the designs.

There are, no doubt, many other uses to which ferro-concrete systems may be applied. Englishmen are naturally conservative; they like to feel that in their adoption of any new system they are not running too great a risk, and a novel form of construction such as this must undoubtedly have some failures, but, paraphrasing the old saying, the writer would urge that "nothing succeeds like failure." It is from failures that the greatest knowledge of true principles can be obtained, and therefore we should be grateful to those pioneers who do venture to take risk, even at the sacrifice of some reputation.

Failures in Reinforced Concrete.

The Chairman here stated that any discussion on the entire subject would now be in order and that the chair was prepared to receive any resolution.

Mr. Mac Clarke F.R.I.B.A. (London): In those papers which have been read before the Congress and elsewhere, it seems to have been accepted that the material or combination now known as reinforced concrete is satisfactory in every respect, and the only remark I see bearing on this particular point is that Professor Henry Adams, in a paper "taken as read," speaks of "failures," and that "nothing succeeds like failure."

No doubt we all would like to learn something by failures, but we are naturally anxious that such failures should occur, if at all, in other people's buildings, and not in our own. Where they do take place, they are not made as public as they should be Of course, it is quite natural for a man not to let his failures be more known about than he can help, but on the other hand, as Professor Adams observes, it is only by such failures that we learn something about a full-sized experiment. We have had a very large number of minor experiments, but not of the failures in a full sized experiment, and that is exactly what we want. In Switzerland, last month I heard a great deal of conversation with regard to the failure of a building at Bâle, but I could not learn from anybody what the actual facts of the case were, and I do not suppose that if I went there now I should be able to find out the cause of this particular episode. Bearing all this in mind, it seems to me that an inquiry in the direction of what failures have taken place and their causes would be desirable.

Another matter to which I think the attention of members connected with this class of construction should be called is whether any data exists as to the life of the steelwork in combination with concrete. Most people know it is a most difficult thing to make concrete sufficiently close or homogeneous that it will not allow the passage of air or moisture. If not consolidated enough to make it impervious to these two agents, deterioration might take place in the reinforcing bars, and the structure would lose all the qualities on which its stability depended, and on which the calculations have been based. I take it that this deterioration may not only damage the concrete itself, but also the steel rods, for once the steel rods begin to rust, the rust on them would damage the concrete by expansion, and it would be quite impossible to ascertain what is the nature and effect of the damage (I am assuming that my premises are correct), before the building is so seriously damaged that collapse might occur. We talk in a light and airy manner about adhesion, Portland cement, concrete and steelwork. We also say that we have seen joists of hoop iron and other sorts of iron taken out of buildings which have been there for 28 years, and that we could see the original glue on them. That I have done myself; but on the other hand I have seen a considerable amount of experimental reinforced concrete, and I have observed that this concrete does not close itself up to the metal and that there are a number of interstices which have never been filled. We must presume that they are filled with something and, if it is not with liquid, it is with some vapour, and this vapour, I take it, is either damp or dry, depending upon the state of the weather. This particular phase of this particular type of construction seems to me to be the one which wants thoroughly going into. If we erect a building two stories high suitable for an agricultural labourers' dwelling, it will not make much difference whether it lasts fifty years or not; but if we build a building of the monumental type, which is supposed to represent a very considerable sum of money, I take it that it is the duty of those who design the building, or at any rate who advocated the use of this material to be prepared to show what its life would be. So far as I have been able to ascertain no sufficient inquiry has been devoted to this particular point.

As to architectural effects, it is, of course, quite possible to stick stuff on to concrete, and I have seen it done abroad. We can cast moulds and place them on buildings, but that is not architecture in the true sense. It is merely sticking a lot of "ornaments" on to a concrete wall. If we are going to descend to this sort of thing in our architecture it would be very much better it we have nothing to do with reinforced concrete at all, for we are going to lose something.

I move the following resolution: "That it is the sense of this meeting that an inquiry into the cases of failure in reinforced concrete and their causes would be most desirable."

The Chairman: I formally second the resolution, and the question is now open for further discussion.

Mr. Sachs: I shall be most happy to support Mr. Max Clarke in his valuable proposal. It is really of the utmost importance we should know what the failures are. I was with the mover in Switzerland a few weeks ago when the accident at Bâle formed the subject of much discussion, and also felt that the time had arrived when the lessons of such failure should be properly recorded and become easily available to architects and engineers in practice. There have been other cases of failure at Berlin, Dusseldorf, at Alexandria (Egypt), and several in the United States, and if independent reports, *i.e.*, not *ex parte* reports, can be put before an independent body, the causes of failure arrived at, and the results summarised, we should have the most valuable information.

Professor Henry Adams, M.Inst.C.E. (London), also rose to support the resolution and said: We are all agreed that ferro-concrete to be satisfactory should be solid, but we have been told in the first place that the American practice allows 2½ in. for the aggregate while the English practice wisely brought them down to 1 in. But neither of these took account of what, to me, is the most important matter of all, and that is the grading of the material to various sizes. This was brought home to me very closely a short time ago, when after the Fire Prevention Committee had discovered that broken brick is one of the best if not the best, materials which could be adapted, a firm in London commenced to manufacture broken brick and screened it to pass a 1 in. mesh. but had all the smaller material thrown away. They threw away what was the most valuable part. If they had simply removed the dust and retained the particles from ¼ in. to 1 in., 1 think, in all cases, they would have obtained a sounder material. When there are alterations to ferro-concrete work and sections are exposed, we all know that spaces do show in the material, and they should not show. If we want proper adhesion to the steel we have the concrete solid. 1 believe that more than one of the failures would be found to arise from the improper mixing of the aggregate, and I look upon the grading of the material as a most important point.

Mr. Brownhead and others having spoken,

The Chairman: From something which has been said it might be in the minds of those present that good practice in America justified the use of 2½ in. stone in reinforced concrete. It is perfectly true that certain building laws and certain underwriters' rules permit of such construction, but it is very far from proof that the best architects in America permitted any such construction. The building laws in many of the American States and cities were diverse, but in the principal cities the building laws were coming rapidly to a form in which they prescribed 1 in. or smaller, and ¾ in. and smaller, of those portions of the concrete which are reinforced with iron. Naturally, in massive concrete, larger stones are permitted. In my own practice, and I think in that of the majority of architects in America who use armoured concrete, it is the absolute rule that in the portions that were reinforced in the girders especially the size of the concrete should be 1 in. or less and preferably ¾ in. and less.

It always seems to me that there are so many sources of possible failure in the use of reinforced concrete, that it ought only to be employed under the most favourable circumstances—that is to say, it should be designed by an expert very capable of calculating the strains, and knowing as much about these strains and the way of meeting them as it is possible to know in the present state of the art. In the second place, the drawings and specifications should be of the most rigorous character, and designed in as great detail as is possible before actual construction. In the third place, the materials should not only be wisely chosen, but they should be submitted to rigorous tests, and, in the last place, the depositing of these materials should be done by persons under the most skilful direction and careful supervision. Only under such conditions can we hope to secure a structure in which we can have faith, and with regard to which we can rest with the assurance that it will be what we hope it will.

The following resolution was then passed:—

"*That it is the sense of this meeting that an inquiry into the cases of failure in reinforced concrete and their causes would be most desirable.*"

Fire Protection.

Mr. Sachs: As the subject of fire protection and reinforced concrete has been so frequently touched upon in the course of the previous discussion I will propose a resolution which may, perhaps, seem a little out of place to those who are conversant with the failures of reinforced concrete in fire, but which I think might serve as a safeguard to many architects in practice. It is "That where reinforced concrete is intended to be fire-resisting the greatest possible care must be taken in the selection of the aggregate, its size, and in the protection of the steel; further that the aggregate does not exceed what will pass through a 1-in. mesh, and that the thickness of the protection should never be less than 2 in." The size of the aggregate is of importance, more important to my mind sometimes than the actual mixture of the aggregate. The protection also is of importance, and the reason why I suggest that 2 in. should be put in the resolution is because so many try to scamp that protection, and I have come across reinforced concrete in which the protection to the steelwork was supposed to be ½ in., but where there has not been ½ in.

I would here like to add one word as to official fire tests. It has been mentioned that 1,400 to 2,000 deg. F. were the conflagration temperatures. That is right both for America, the Continent, and for us. It has been further stated that the American rules for tests require a temperature of 1,700 deg. F. The "universal standards" used in this country and arrived at by the International Fire Prevention Congress of 1903, when some fifteen governments and 200 public bodies were represented, was 1,800 deg. F. It would be well to here put on record that in arriving at the figure 1,800 deg. and the fixing the duration of the test it was born in mind that in all test pieces great care is taken to produce perfect work, but that in ordinary building practice the work would scarcely be of the same perfect quality as the work carried out for testing purposes. Thus both in temperature and time the requirements are severe for the perfect test pieces and the margin for ordinary work has been provided for.

Mr. Edwin Seward, R.C.A. (Cardiff), seconded.

Mr. Edwin W. Fritchley (Bombay), supporting the resolution said: In India I have used armoured concrete and crushed stone concrete for the last three or four years. We sieved our stone. It is crushed bay sale, and when powdered is as good as sand. We had three or four grades, one between 1 in. and 1½ in., another between ⅜ in. and ¾ in., and a third is almost a powder.

After some discussion as to how the resolution should be taken, *i.e.*, as a whole or in parts, Mr. Sachs suggested that the resolution be taken on general lines only without the detail of dimensions.

The following resolution was then passed:—

"*That where reinforced concrete is intended to be fire resisting the greatest possible care must be taken as to the nature of the aggregate and its size and also as to the protection of the steel.*"

MEMORANDA.

Memoranda and News Items are presented under this heading, with occasional editorial comment. Authentic news will be welcome.—ED.

Cement for San Francisco.—In an important article of August 13th, *The Times* dwells upon the great demand for cement for San Francisco and the improvement in the cement trade generally.

The importance of the San Francisco disaster to the cement trade cannot be underrated, and to what extent it may be affected can be observed from the general advocacy of a greater use of cement in brickwork and a greater use of concrete and reinforced concrete on the Pacific coast.

The following are among the lessons of the San Francisco conflagration reported to the Board of Fire Underwriters by their engineer, Mr. S. Albert Reed :—

1. The importance of good bricklaying and mortar with cement instead of lime.
2. The encouraging possibilities of re-inforced concrete, and the importance of good engineering in its installation.

* * *

Splintered Timber Piles.—During the formation of the foundations for the Naval Engineering Building at the Massachusetts Institute of Technology, some three hundred timber piles were driven. The piles were of spruce, and measured 28 ft. long by 6 in. diameter at the point and from 9 in. to 12 in. at the top, and were driven to refusal by a 2,500-lb. monkey falling from the height of 15 ft. No difficulty was experienced in driving the piles, and no evidence was presented suggesting injury until after the building had been erected. Then excavations revealed the fact that several of the piles were seriously splintered and crippled, some of them being literally split up into matchwood. Although the case here mentioned is probably of unusual character, it may easily recur in soil containing boulders a short distance below the surface. The fact that no indication of injury is likely to be given is one that does not tend to increase confidence in timber piling, and distinctly suggests the advisability of adopting reinforced concrete piles sunk in such manner as to avoid any risk of damage.

* * *

Concrete Flags.—We are pleased to observe that concrete flags are not only being used for pavement work as has mainly been the case heretofore, but that they are being found useful for lining reservoirs, and we have before us also a case where they were used for lining a large municipal open-air swimming bath at Chelmsford, where close on 1,500 square yards of concrete flags have been used. The work of the Chelmsford swimming baths in question was executed under the supervision of the borough engineer, Mr. Cuthbert Brown, and although the bath measures five-sixths of an acre (150 ft. by 100 ft.) the work was carried out at a very moderate expenditure.

* * *

Trade Announcements.—The London representative of the Hennebique system (Mr. L. G. Mouchel, C.E.), has sent us an interesting list of new contracts entered into, and we observe that several of our railway companies are now actively engaged in reinforced concrete construction.

An interesting application of this system as far as England is concerned, will be found in the gallery and columns for the King's Theatre, Sunderland, for which Messrs. S. F. Davidson, of Newcastle, are the contractors.

TESTS WITH CONCRETE
AT HOME AND ABROAD.

We consider that the absence of reliable information as to the various tests carried out with concrete both at home and abroad has frequently led to misconceptions as to the qualities of this material, and we shall thus for the present accord considerable space to the presentation of authentic data that may be of service to those employing concrete in its various forms. The tests which will particularly call for our attention are those relating to strength, fire-resistance, and waterproofing.—ED.

SOME AMERICAN TESTS WITH REINFORCED CONCRETE.

Summarised and Annotated.

By CHARLES F. MARSH, M.Inst.CE.

Shearing in Beams.

SOME very interesting tests on the "Shearing of Reinforced Concrete Beams," were described in a paper read before the Western Society of Engineers by Mr. J. Harding on October 25th, 1905.

These experiments were carried out for the Chicago, Milwaukee and St. Paul Railway on beams reinforced with about 75 per cent. of reinforcement to the area of concrete above the centre of the bars. The concrete was mixed in the proportion of 1 of cement, 2 of sand, and 5 of crushed limestone to pass a 2-in. mesh. The bottom surface to the top of the rods being formed of 1 to 2 mortar without any stones.

Sketches showing the beams tested are given in *Fig.* I., three of each kind being experimented upon. The deformations at the upper and lower fibres were taken on one of each kind.

Table I. gives the details of the tests, the averages of each set of three beams being taken.

The conclusions arrived at from these experiments were as follows:—

(1) That 75 per cent. of reinforcement is as much as can economically be used in beams sustaining heavy loads and subjected to large shearing stresses.

(2) Diagonal reinforcements should be used at the ends of all large concrete beams, not only to develop the full strength but also to prevent sudden failure.

(3) The diagonal reinforcements should be brought well up to the top of the beam and securely anchored against slipping.

(4) The use of small bars is preferable; the use of bars larger than 1 in. is objectionable, both from theoretical and practical standpoints.

(5) The ultimate strength of a reinforced concrete beam is reached when the steel has been stressed to its elastic limit.

(6) The location of the neutral axis varies with the amount of steel and the class of the concrete. With 75 per cent. of reinforcement and with average concrete the distance from the top of the beams to the neutral axis will be about one-third the distance from the top of the beam to the centre of the rods.

(7) That it makes very little difference whether the distance from the centre of the compressive resistance is taken as two-thirds the distance the neutral axis to the top of the beam as for a triangular distribution, or as three-fifths as for a parabolic distribution, the difference in the resulting moment being less than 3 per cent.

The resistance of the beams reinforced with straight bars only was much more variable than the resistance of those with inclined bars.

In one beam of the third series it was discovered after breaking it up that all, except the outer diagonal bars, had slipped down to the bottom of the beam, and the failure crack extended across their upper ends, and in another of the same series the failure was undoubtedly due to the slipping or pulling out of the

TABLE I.

No. of Beam.	Description of reinforcement.	Percentage of reinforcement at centre of span.	Maximum tension in steel from deformations. Pounds per sq. inch.	Maximum compression in concrete from deformations. Pounds per sq. inch.	Maximum end shear. Pounds.	Maximum vertical shear. Pounds per sq. inch.	$\frac{M}{bh^2}$*	Maximum variations in ultimate bending moments for the 3 beams of each set.	Description of failure.
1	Ransome ..	75	31,500	1,155	22,325	149	249	40%	All beams showed quick diagonal failure and one showed further a horizontal shearing along the bars.
2	Ransome ..	75	60,300	2,700	34,875	233	392	2½%	All beams showed a slow diagonal failure.
3	Ransome ..	75	61,200	2,090	43,225	277	444·5	16%	Two beams showed a quick diagonal failure, one developing a crack along the bars. The other beam failed in tension with slow compression failure in concrete at ultimate load.
4	Kahn ..	68	36,900	1,365	28,525	162	232	7½%	All beams failed in tension showing slight compression at ultimate load.
5	Johnson ..	72	59,700	2,140	47,875	272	412	12%	One beam showed slow diagonal failure and the other two slow failure in compression.
6	Johnson ..	72	42,600	1,560	32,925	192	202	33%	All beams showed a quick diagonal failure.
7	Plain round	75	37,200	1,540	25,810	162	254	42%	All beams showed a quick diagonal failure.
8	Plain round	75	40,800	1,610	31,640	198	312	5%	All beams showed a slow tension failure.
9	Johnson ..	75	36,600	1,560	35,860	183	261	20%	All beams showed a quick diagonal failure.
10	Johnson ..	75	77,300	2,590	55,640	300	407·5	6%	All beams showed a quick diagonal failure.

* *M = bending moment ; b = breadth ; and h = depth from top of beam to centre of reinforcement.*

diagonals. These failures indicate the necessity of extending the shearing bars as closely up to the top of the beams as possible and of securely anchoring their ends. Beams No. 8 failed apparently by the rods slipping before the full strength of the concrete in compression was developed. These rods had a 3-in. right angle bend at the ends, and in one case the concrete was broken away at one end of a rod, clearly showing that the rod had moved.

The interesting results of these tests would have been increased if some experiments had been carried out on beams with vertical stirrups as shearing reinforcement.

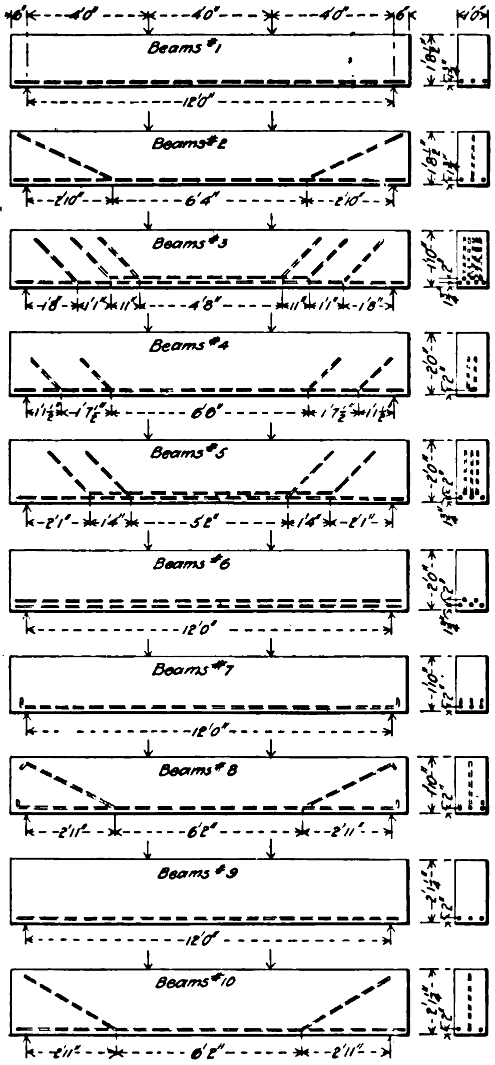


Fig. I.

Some General Tests.

Several tests were made on reinforced concrete beams at the St. Louis Exhibition. Four beams were tested in the laboratory, three of which (two rectangular and one of T-section) were made according to the Hennebique system; and the other (rectangular) according to the Kahn system. The rectangular beams were made under identical conditions, and were designed to carry the same load, using the same percentage of reinforcing metal.

These beams were made in the open air, and were not kept damp after moulding. The forms were removed only just before the tests were made at the end of sixty days after moulding.

The concrete was of poor quality, due to the small crushing resistance of the aggregate, and this caused the beams to fail before the fall resistance of the steel was developed, although in both systems steel was inserted to aid the concrete in compression.

In the Kahn beams the resistance would probably have been greater had the compression reinforcements continued to the end of the beam, as the beam failed by the concrete crushing at the ends of the top bars.

A short description of the tests is given below:—

BEAM 1, KAHN SYSTEM (*Fig.* II.).—Length over all, 11 ft. $11\frac{3}{4}$ in.; clear span, 10 ft.; breadth, $6\frac{1}{8}$ in.; depth over all, $8\frac{1}{4}$ in.; depths to centre of steel, $7\frac{1}{4}$ in.; compressive strength concrete, 1,747 lb. per square inch; weight of beam, 593 lb.; mixture, 1:2:4;

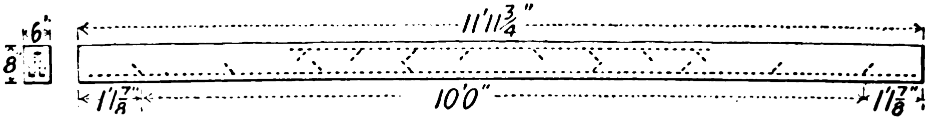


FIG. II.

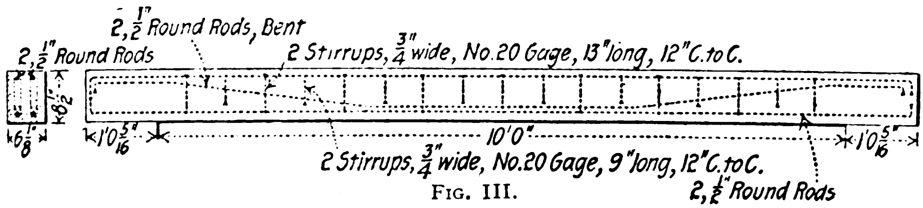

2, ½" Round Rods, Bent
2, ½" Round Rods
2 Stirrups, ¾" wide, No. 20 Gage, 13" long, 12" C. to C.
8½"
6⅛"
1'0 5/16"
10'0"
1'0 5/16"
2 Stirrups, ¾" wide, No. 20 Gage, 9" long, 12" C. to C.
2, ½" Round Rods

FIG. III.

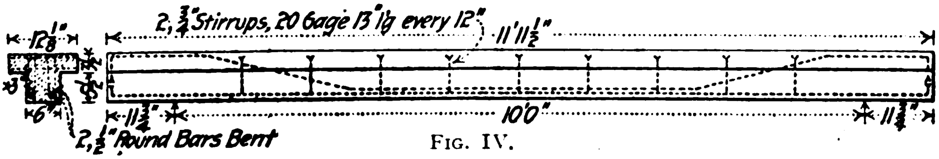


FIG. IV.

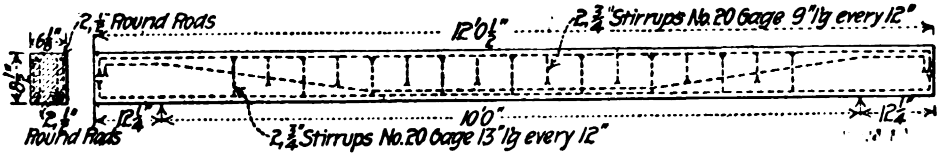

2, ½" Round Rods
6⅛"
12'0½"
2, ¾" Stirrups No. 20 Gage 9" lg every 12"
2, ½" Round Rods
12¼"
10'0"
12¼"
2, ¾" Stirrups No. 20 Gage 13" lg every 12"

FIG. V.

reinforcement in top, one ½-in. Kahn bar 9 ft. long; reinforcement in bottom, two ½-in. Kahn bars 11 ft. 11¾ in. long.

Steel in tension	.. ..	1·59%
Steel in compression	..	·80%
Total steel	.. ..	2·39%

Loads. lb.	Deflection. in.	Remarks.
3350	5/16	Crack appeared on right under end of top of reinforcing bar.
5350	15/32	Crack appeared on left under end of top of reinforcing bar.
7770	7/84	Failed by concrete crushing around ends of top reinforcing bar. Concrete buckled at the ends of top bar.
7830		

BEAM 2, HENNEBIQUE SYSTEM (*Fig.* III.).—Length over all, 12 ft. ⅝ in.; clear span, 10 ft.; breadth, 6⅛ in.; depth over all, 8½ in.; depth to centre of steel, 7½ in.; weight of beam, 620 lb.; mixture, 1:2:4:; compressive strength of concrete, 60 days, 1·747 lb. per square inch.

Steel in tension	.. ..	1·60%
Steel in compression	..	·80%
Total steel	.. ..	2·40%

Loads. lb.	Deflection. in.	Remarks.
6350	9/16	Hair cracks appeared on either side of centre, very faint.
8150	15/16	Cracks became more general.
8450	1 13/16	Failed by concrete buckling in centre of beam.

BEAM 3, HENNEBIQUE SYSTEM (*Fig.* IV.).—Length over all, 11 ft. 11½ in.; clear span, 10 ft.; breadth, 12⅛ in.; depth over all, 9 in.; depth to centre of steel, 7½ in.; weight of beam, 876 lb.; mixture, 1:2:4; strength of concrete, 60 days, 1,747 lb. per square inch.

Loads. lb.	Deflection. in.	Remarks.
7950	15/32	First hair cracks appeared in centre.
8750	7/8	Failed by concrete crushing at top in centre of beam

BEAM 4, HENNEBIQUE SYSTEM (*Fig.* V.).—Length over all, 12 ft. ½ in.; clear span, 10 ft.; breadth, 6⅛ in.; depth over all, 8½ in.; depth to centre steel, 7½ in.; weight of beam, 614 lb.; mixture, 1:2:4;

compressive strength, 60 days, 1,747 lb. per square inch.

Steel in tension	1·60%
Steel in compression ..	·80%
Total steel	2·40%

Loads. lb.	Deflection. in.	Remarks.
6350	1/2	Faint hair cracks on either side, centre very faint.
8650	1	Failure by concrete buckling at top in centre.

A further series of tests were carried out at the expense of the Trussed Concrete Steel Company, of Detroit, Michigan, and the Hennebique Construction Company, of New York.

These tests were upon reinforced concrete beams of 15-ft. span, and a tile floor on the Kahn system of 16½-ft. span. The aggregate used for these beams was of poor quality, being similar to that used for the beams mentioned above, and the beams consequently failed under comparatively small loads, the full tensile resistance of the steel not being brought into play.

The beam forms were well wetted before the concrete, which was mixed, very wet, was deposited, and the moulds were removed after ten days. The beams remained in the air without being wetted or kept damp, until tested sixty days after moulding.

The unequal loading of the ground supporting the beams caused the overturning of beams A and B, and possibly

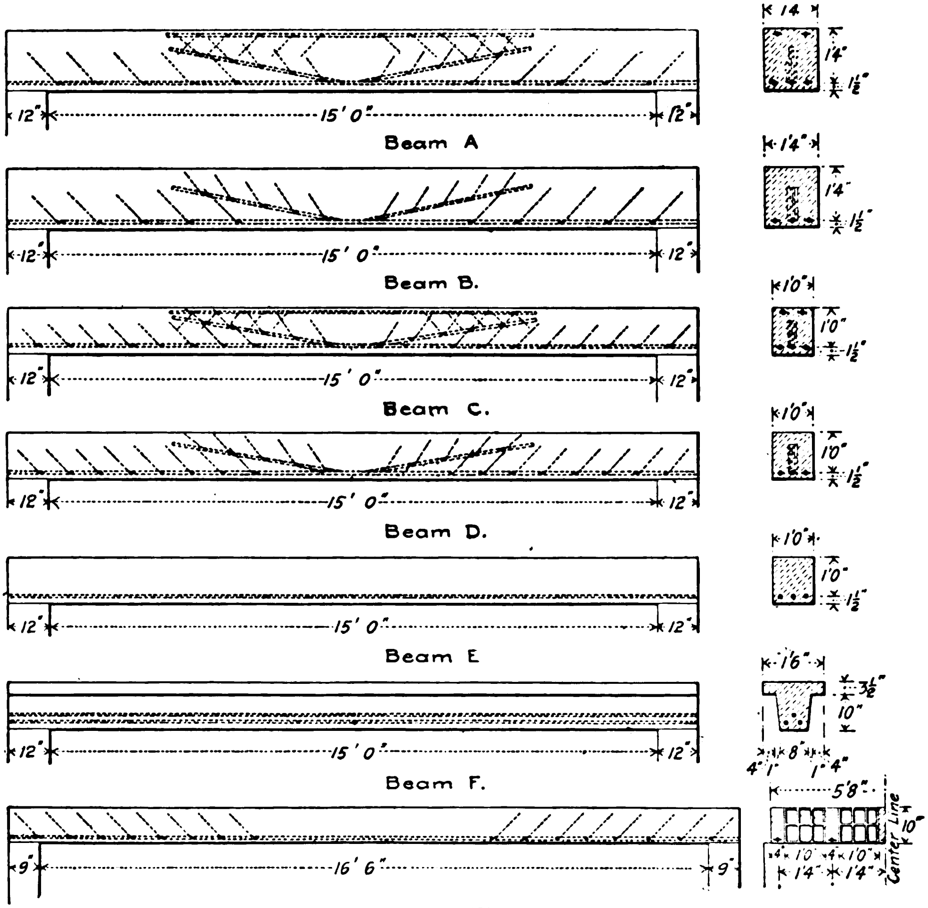


FIG. VI.

the failure by shearing of the overhanging slab in the T-beam F.

Fig. VI. shows the dimensions and the reinforcement of the several beams and a short description of the test is given below.

The principal lesson to be learnt from these tests is the necessity for the employment of an aggregate of sufficient compressive resistance.

The following are the results of the tests of these beams:—

BEAM A.—Built September 13th, 1904; tested December 7–14th, 1905. Length overall, 17 ft.; clear span, 15 ft.; breadth, 16 in.; depth over all 17½ in.; depth to centre of steel 16½ in.; reinforcement in bottom, two 1-in. Kahn bars, 17 ft long; reinforcement in centre, one ¾-in. Kahn bar 9 ft. long, bent up slightly; reinforcement in top, two ¾-in. Kahn bars, 9 ft. long, inverted; weight of beam, 4,600 lb.; mixture, 1:2:4; area steel in tension, 3·62 or 1·41 per cent; area steel in compression, 1·56 or ·60 per cent.; total steel, 5·18 or 2·01 per cent.; compressive strength of concrete, 1,740 lb. per square inch.

Loads. lb.	Deflection. in.	Remarks.
37458	7/32	Two faint hair cracks, one at each end of bend, bar in centre; beam started to overturn, bearings sinking unequally.

Beam unloaded and straightened.

No deflection observable, then began loading at 37,458 lb.

44723	1/4	Four hair cracks (2 more) on each side of centre.
50000	5/16	Rain stopped, loading beam overturned, due to unequal settling of foundations.
52962	3/32	Set in beam.
60856	5/8	Beam overturned.

Foundations again settling unequally, beam straightened, one hair crack in centre 2, 3 ft. 6 in. on either side of centre of beam; ⅜ in. deflection set in beam. Foundations relevelled, bearing area increased and beam reloaded.

Several hair cracks from top ⅛ in. opening travelling off in both directions horizontally, middle each 8½ in. from top.

Loads. lb.	Deflection. in.	Remarks.
63811		Two more hair cracks appeared on either side of centre line.
74941	1 1/8	
75000		One crack 18 in. from centre line, 9 in. from top.
		One crack 36 in. from 11 in. from
		One crack 56 in. from 7 in. from
94512		Failed.

Weight beam, 4,600 lb.

Total load, 99,112 lb.

KAHN SYSTEM HOLLOW TILE FLOOR CONSTRUCTION.—Built September 21st, tested November 30th, December 1st, 2nd, 1905. Length over all, 18 ft.; clear span, 16 ft. 6 in.; width, 5 ft. 8 in.; depth, 10 in.; tile, 10 in. by 12 in.; beam joist, five, 4 in. by 10 in., 18 ft. long, ¼-in. centers; reinforcement, each joist, one ⅝-in. Kahn bar, 18 ft. long; mixture, 1:3:5; area steel, each joist, 0·78 in. or 2·30 per cent.; weight of slab, 5,800 lb.

Loads. lb.	Deflection. in.	Remarks.
22200	1/2	Hair cracks across centre exactly.
34634	2 1/2	Two vertical cracks appeared 3 in. off centre line on either side.
35611		Concrete commenced to crush on top over last cracks, loading stopped, beam kept cracking and slowly deflected until it failed at 12.15 (20 minutes), with centre cracks opening up and another 7 ft. off centre line concrete at centre crushing out and a crack running along line of steel from centre to right three feet. Breaking load 500 lb. per square foot. The dimensions of slab are shown in Fig. VI.

BEAM B.—Built September 12th; tested December 5th, 6th, 1905. Length over all, 17 ft.; clear span, 15 ft; breadth, 16 in.; depth over all, 17½ in.; depth to centre of steel, 16 in.; reinforcement in bottom, two 1-in. Kahn bars, 17 ft. long; reinforcement in bottom, one ¾-in. Kahn bar 9 ft. long, bent slightly upwards; area of steel, 3·62 square inches or 1·41 per cent.; weight of beam, 4,600 lb.; mixture, 1:2:4; compressive strength of concrete, 1,740 lb. per square inch.

Load. lb.	Deflection. in.	Remarks.
31487	11/32	One hair crack on bottom of beam under each bent bar.
33403	11/32	Two more hair cracks appeared.
47817	3/4	Two more hair cracks appeared nearer bearings.
60911	2 11/32	Beam overturned.

BEAM C.—Built September 12th; tested December 3rd, 4th, 5th, 1905. Length over all, 17 ft.; clear span, 15 ft.; breadth

12 in.; depth over all, 13½ in.; depth to centre of steel, 12 in.; weight of beam 2,677 lb.; mixture, 1:2:4; reinforcement in bottom, two ¾-in. Kahn bars 17 ft. long; reinforcement in bottom, one ¾-in. Kahn bar, 9 ft. long, bent up slightly; reinforcement in top 2¼ in. Kahn bars 9 ft. inverted; area of steel in tension, 2·34 square inches; area of steel in compression, ·76 square inch; total area of steel, 3·10 square inches; per cent. of steel, 2·15; compressive strength of concrete, 1,740 lb. per square inch.

Load. lb.	Deflection. in.	Remarks.
21688	15/32	Hair cracks appearing.
30878	1 11/16	
	—	Failed.

Dimensions, etc., shown in Fig. VI.

BEAM D.—Built September 13th; tested December 2nd, 3rd, 1905. Length over all, 17 ft.; clear span, 15 ft.; breadth, 12 in.; depth over all, 13½ in.; depth to centre of steel, 12 in.; weight of beam, 2,677 lb.; mixture, 1:2:4;. reinforcement in bottom, two ¾-in. Kahn bars, 17 ft. long; reinforcement in bottom, one ¾-in. Kahn bar 9 ft. long, bent up slightly; area steel in tension, 2·34 square inches; per cent. of steel, 1·63; compressive strength of concrete, 1,740 lb. per square inch.

Load. lb.	Deflection in.	Remarks.
32663	1¾	Failed slowly 4 ft. 6 in. from each end of beam.

For dimensions, etc., see Fig. VI.

BEAM E.—Built September 13th; tested December 1st, 1905. Length over all, 17 ft.; clear span, 15 ft.; breadth, 12 in.; depth over all, 13½ in. depth to centre of steel, 12 in.; weight of beam, 2,677 lb.; mixture, 1:2:4; compressive strength of concrete, 1,740 lb. per square inch; reinforcement in bottom, three 1-in. round bars, 17 ft. long; area of steel, 2·35 square inches; per cent. 1·63.

Loads. lb.	Deflection. in.	Remarks.
26460	11/16	Two hair cracks, one on either side of the centre line.
33108		Failed.

A series of vertical cracks appeared until the beam failed suddenly by horizontal shear at one end entirely. Bars again slipped as beam collapsed. Dimensions of beam given in *Fig.* VI.

BEAM F.—Built September 13th; tested December 1st. 1905. Length over all, 17 ft.; clear span, 15 ft.; breadth at base, 8 in.; at top, 18 in.; depth over all, 13½ in.; depth to centre of steel, 11½ in.; reinforcement in bottom, two 1-in. round bars, with one 1-in. round bar just above; mixture, 1:2:4; weight of beam, 2,529 lb.; compressive strength of concrete, 1,740 lb. per square inch; per cent. of steel, 1·63; area of steel, 2·35 square inches.

Loads. lb.	Deflection. in.	Remarks.
18898	9/16	Two hair cracks 1 ft. off centre line, either side
20166		Failed.

Bars sliding at beam collapsed. The slab sheared off on one side as will be seen; this was probably due to lack of uniformity of load. The bars did not slip until the beam collapsed. There was no reinforcing in the slab. The dimensions of beam and other information can be obtained from *Fig.* VI.

OFFICIAL FIRE TESTS WITH REINFORCED CONCRETE FLOORS.

WE are informed that on July 25th a reinforced concrete floor of slag concrete reinforced by "indented bars," constructed by the Patent Indented Bar Co., of Queen Anne's Chambers, Westminster, S.W., was tested by the British Fire Prevention Committee at their Regent's Park Testing Station, with a view of its obtaining the standard of fire resistance known as "Fully Protective" (Class B.), which necessitates the application of fire to a temperature of about 1,800 deg. F. for a period of four hours, followed by the application of water for five minutes, the load on the floor being 2½ cwt. per foot super.

The floor under test covered a space 15 ft. by 22 ft. 3 in., the area being divided into three bays, and there being two reinforced concrete beams of 15 ft. span.

The test was conducted under the committee's usual procedure by a special sub-committee. The committee's council was represented by Sir James Williamson, C.B., late Director of Dockyards. Various Government departments and Municipal authorities interested, were represented. The chairman of the executive and the general hon. secretary received the members and visitors.

The floor attained classification.

NEW WORKS IN CONCRETE

AT HOME AND ABROAD.

Under this heading reliable information will be presented of new works in course of construction or completed, and the examples selected will be from all parts of the world. It is not the intention to describe these works in detail, but rather to indicate their existence and illustrate their primary features, at the most explaining the idea which served as a basis for the design.—ED.

NEW FACTORIES FOR MESSRS. ROWNTREE AND CO., LTD., YORK.

MESSRS. ROWNTREE AND CO., LTD., of York, are erecting two new factories in reinforced concrete.

The first, *i.e.*, smaller of these was commenced in the spring, the Yorkshire Hennebique Contracting Co. having the contract and Mr. W. H. Brown acting as architect.

The buildings are designed to carry heavy loads. Thus of the larger block we understand that the ground floor has to carry a load of machinery equal to 10 cwt. to the square foot, and the first floor 7½ cwt. per square foot; the second and third floors 5 cwt. per square foot and the fourth floor and roof 3 cwt. per square foot.

In order to carry these loads the whole of the site is covered with a 12 in. reinforced concrete slab.

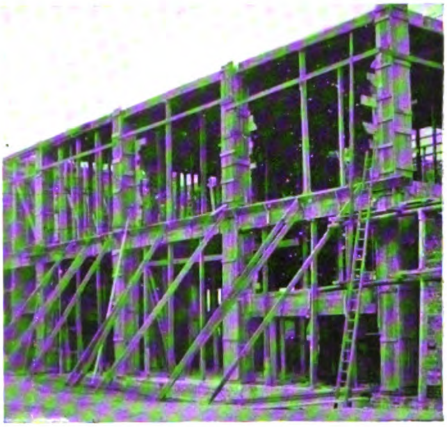
The main stanchions in the basement are 32 in. by 32 in., with bases extending on the slab 15 ft. by 15 ft. each; each of these columns are re-inforced with No. 15 bars 2½ in. in diameter. It should be noted that the temperature will always be kept below zero, while the temperature on the ground floor will be 90 deg. F. The angles of all columns are rounded and all reinforced bars and rods are protected with at least 2 in. of concrete. The floors are all lipped up or inclined towards the staircases and lift openings, as a precaution against water damage in case of fire.

The interior of this building is lined with white glazed tiles throughout. The exterior is built of Castleford facing brick with Bradford stone dressings. The roof is formed into two large cisterns.

The building contains 1,421,000 cubic feet, and the architect informs us that it will cost 4·7d. per foot cube.

The two new factories should afford excellent examples of reinforced concrete construction intended to be fire-resisting, and we are pleased to observe that those in authority have apparently been suitably advised in this all-important matter and have insisted upon the necessary precautions being taken. Such attention is still the exception.

We trust on a future occasion to deal with these buildings in detail.



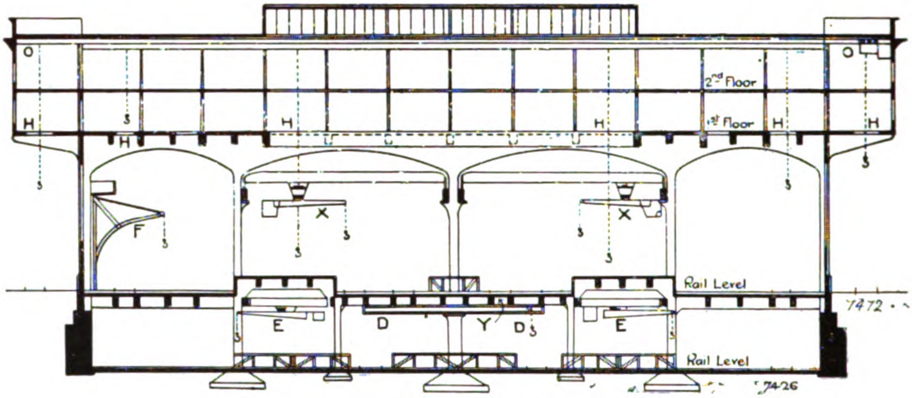
THE ROWNTREE WORKS.
The first Reinforced concrete factory in course of erection.

NORTH-EASTERN RAILWAY GOODS STATION AND WAREHOUSE, NEWCASTLE-ON-TYNE.

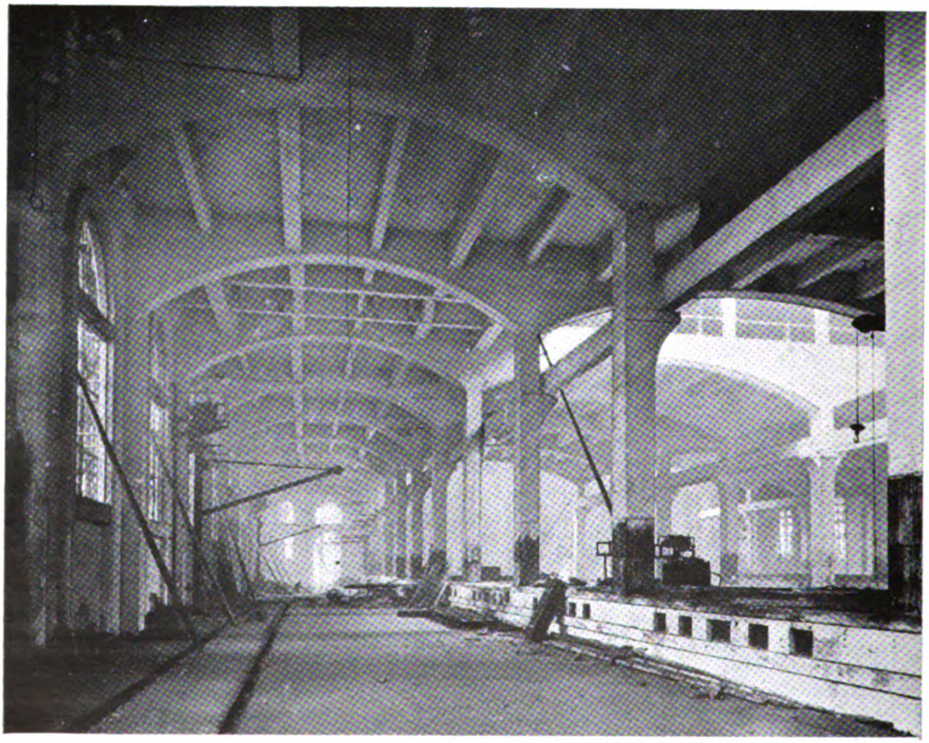
THIS new goods station is a striking example of the economic application of reinforced concrete for railway station and warehouse work, and calls for close attention of all railway engineers, as also those administrative officials of railway companies who have to deal with the financial side.

The building is situated at New Bridge Street, Newcastle-on-Tyne, and in addition to the station accommodation, provision is made on a large scale for warehousing general merchandise and for the storage of flour.

There is a basement designed as a low level goods station, with four tracks for trucks and ample space for dealing with inward and outward goods. On the ground floor—designed as a high level goods station—there are two sidings into which trains will be run, and there are some powerful hoists for transferring trucks from one level to another.

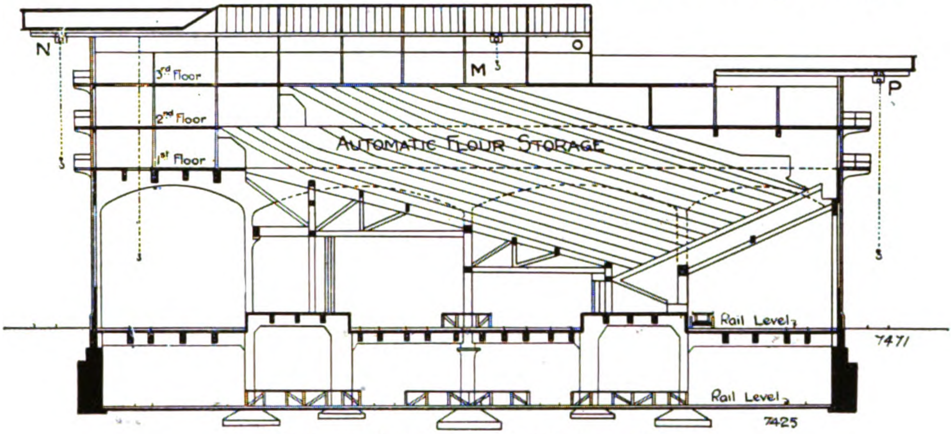


Section of Goods Station.

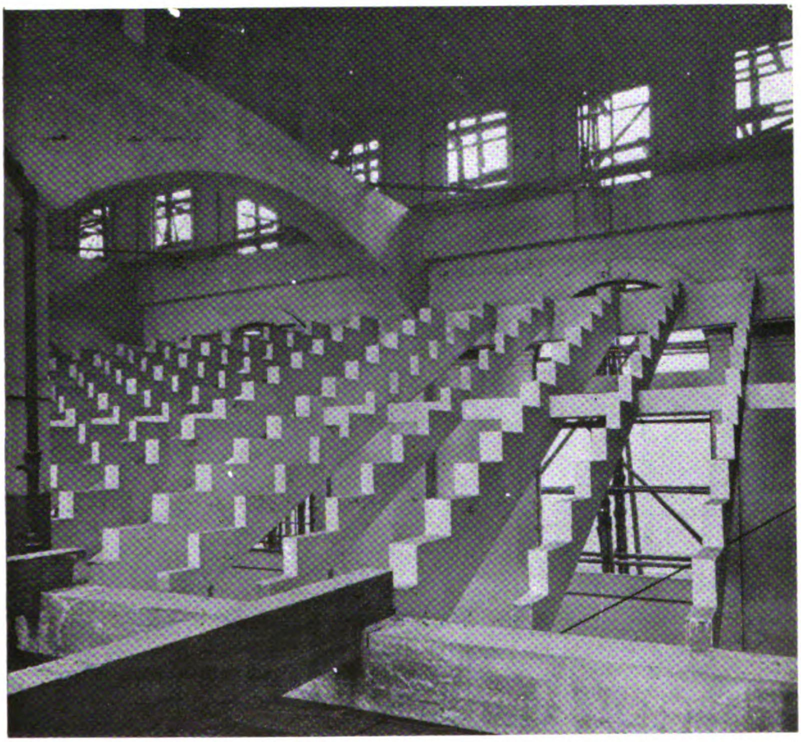


North-Eastern Railway Goods Station, Newcastle.
Interior view of Ground Floor

The upper floors of the building, which are used for storage purposes, are partly designed as an ordinary warehouse and partly as a special flour store with inclined floor. Over the whole there is a flat reinforced concrete roof available for the storage of empties.



Diagrammatic Section of Automatic Flour Storage.



North-Eastern Railway Goods Station, Newcastle
Interior view of automatic flour storage.

As to the flour store, of which we present an illustration, it is capable of holding 2,100 tons or 16,800 twenty-stone sacks. As indicated, the whole is in reinforced concrete and the work includes beams with spans of 35 ft.

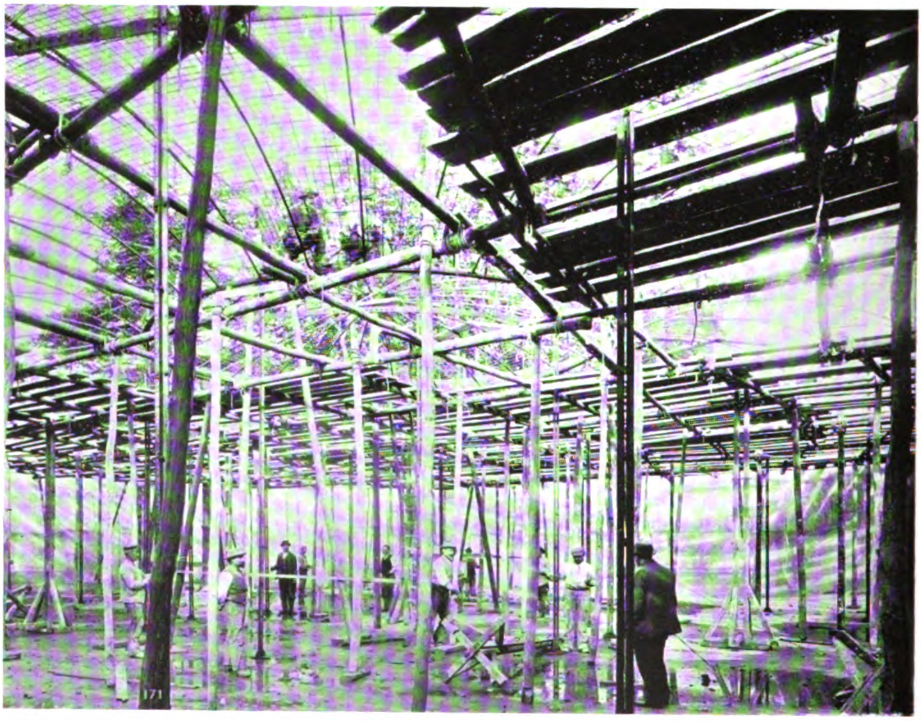
In the floor system immediately above the low level station the transverse girders, spaced 33 ft. apart centre to centre, are 1 ft. 6 in. wide by 2 ft. 9 in. deep, two portions of the girders on the inner side of the outermost row of columns being raised so as to form platforms for handling merchandise. The longitudinal girders of the same floor system are 1 ft. wide by 2 ft. 3 in. deep, and the spacing varies according to the requirements of the spans, from 4 ft. to nearly 7 ft. These girders are monolithic with the columns, and the whole system is connected by a floor slab, 9 in. thick, forming a compression flange common to the network of the beams. Upon and partly embedded in the slab are sleepers carrying the various rail tracks, and the floor surface of the high level station is formed by a layer of concrete 6 in. thick.

Turning to the sections, it may be of interest to note that D D indicate cranes revolving round a pillar; that E E indicate overhead cranes; that O O indicate travelling conveyors which can be worked through the openings H H H.

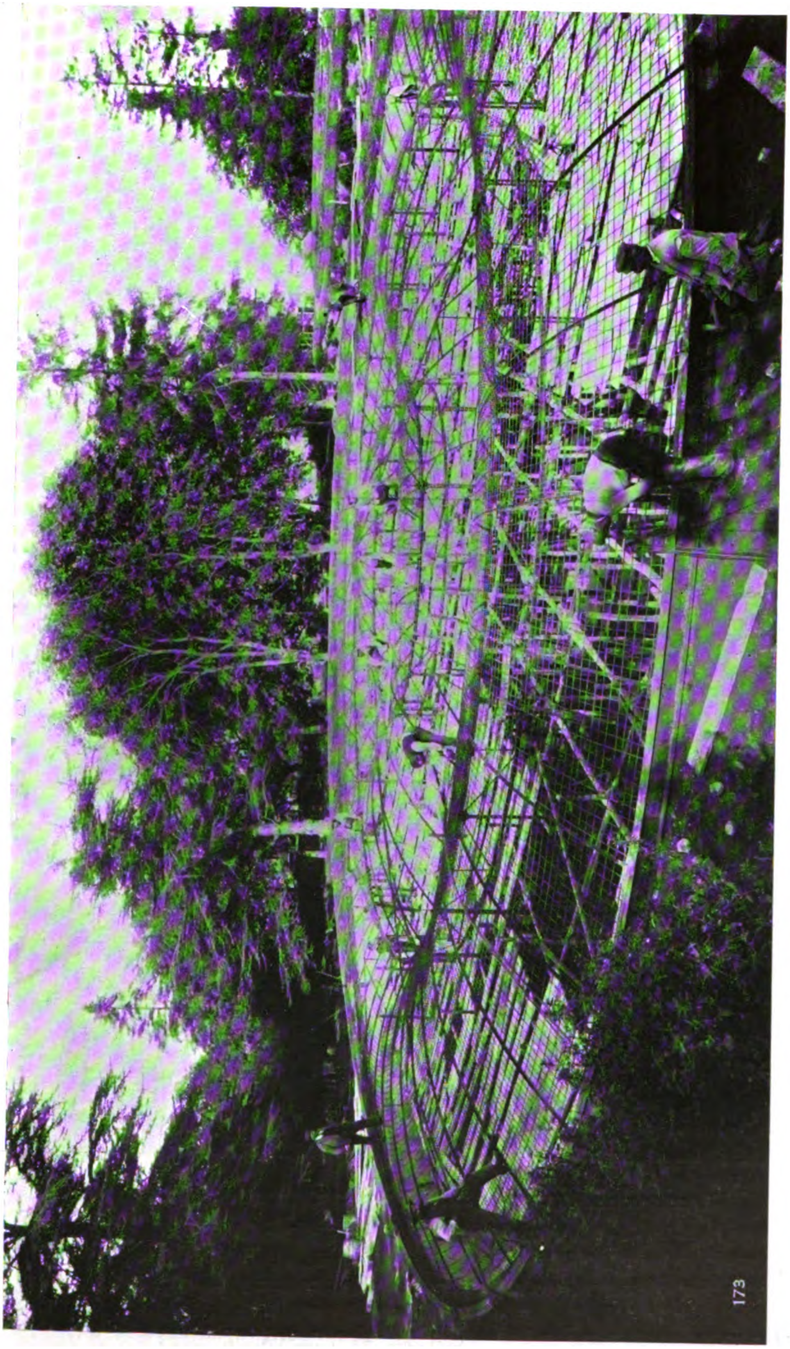
The general organisation of the work as now carried out at this goods station, is very near perfection.

The results of the tests with the work when completed are stated to have been eminently satisfactory. Mr. W. Bell, F.R.I.B.A., Architect to the North Eastern Railway, prepared the design and supervised the execution of this work. The system of reinforced concrete applied was the Hennebique system, and the contractors were Messrs. Joseph Howe and Co., of West Hartlepool. The iron bars throughout were provided by the Consett Iron Company, Ltd.

We are indebted to the Editor of the *Railway News* for the excellent photographic illustrations, and for the sections to the Editor of the *Engineering Review*.



REINFORCED CONCRETE RESERVOIR AT CHATILLON, FRANCE.
In course of construction.



Reinforced Concrete Reservoir at Chatillon, France.
In course of construction.

REINFORCED CONCRETE RESERVOIRS IN FRANCE.

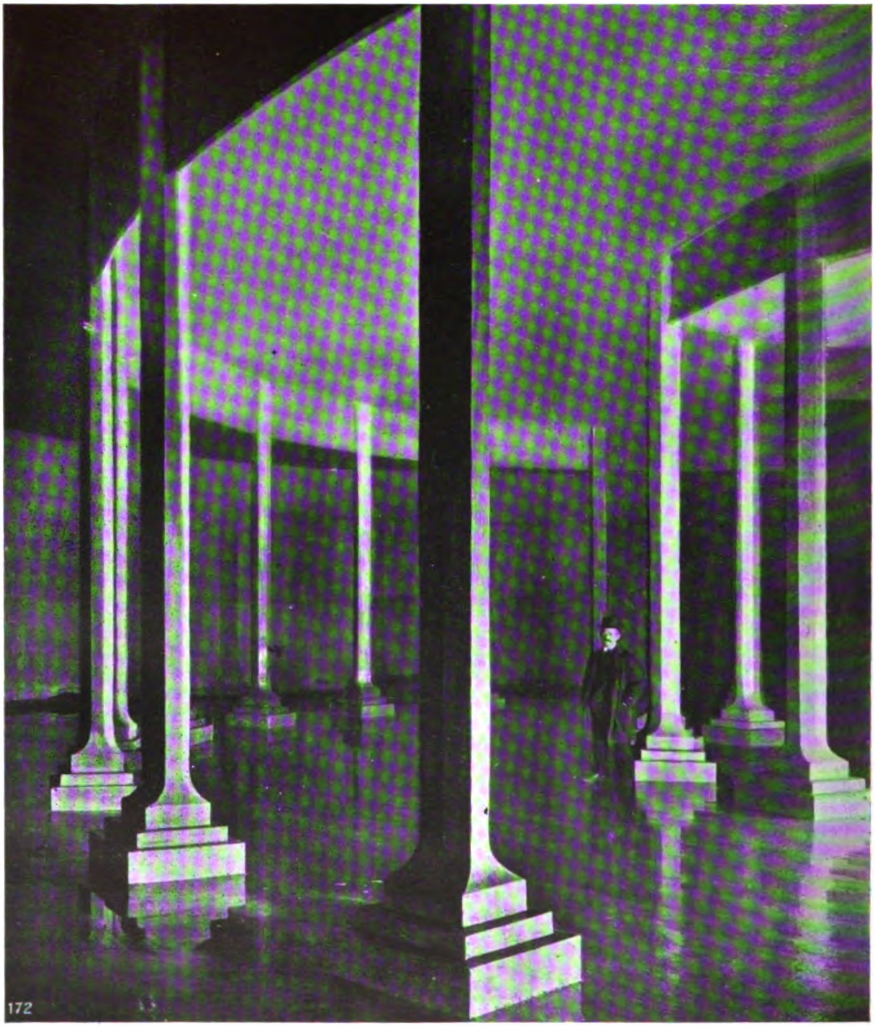
WE have dealt with the reinforced concrete water mains in the form of a special article by Mr. R. H. Wyrill, M.Inst.C.E. We have also presented examples of recent water towers erected in this material.

We now also present some views of a large reservoir completed at Paris under the supervision of Monsieur Boutan by Messieurs Chassin, the specialist contractors.

The reservoir was for the Compagnie Generale des Eaux, and is located at Chatillon.

The capacity of the reservoir is 4.000 cubic metres.

The photographs explain themselves and show an exceptionally daring design.

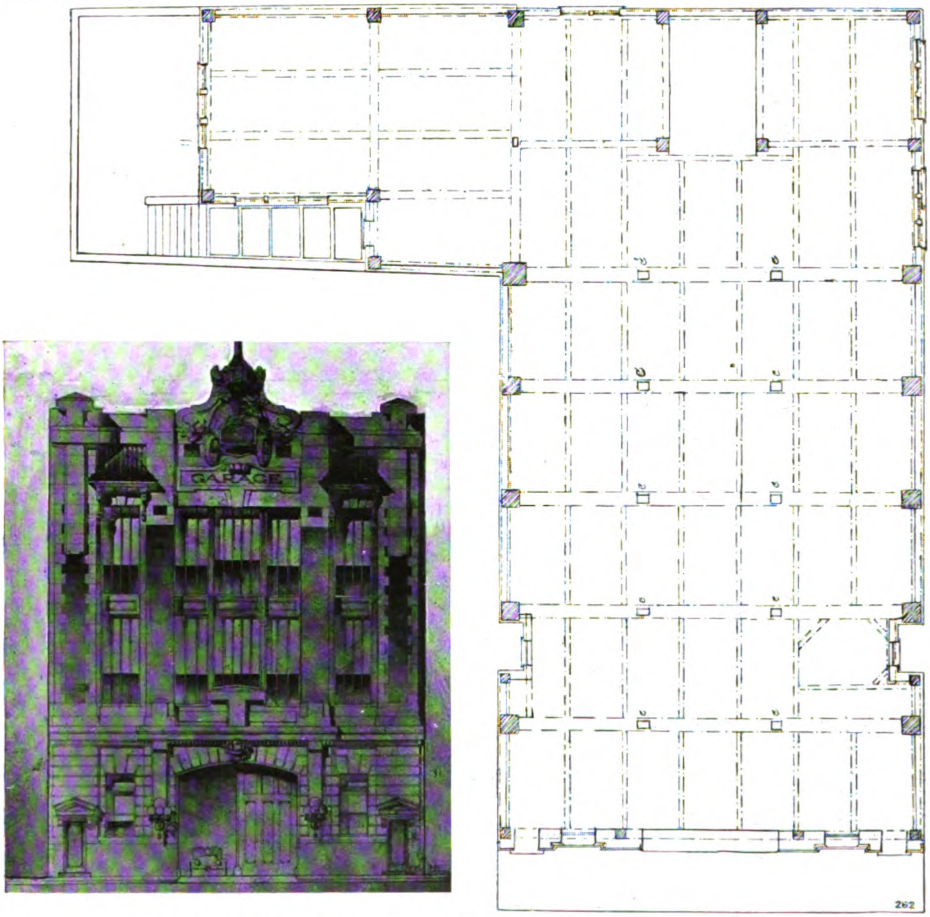


REINFORCED CONCRETE RESERVOIR AT CHATILLON, FRANCE.
Interior view upon completion.

A MOTOR GARAGE OF REINFORCED CONCRETE.

New York, U.S.A.

THIS building is designed as a public garage for the storage and stabling of automobiles. It contains a good repair department and machine shop as well. There are three floors and basement. The basement has about 9 ft. head room, the first floor 18 ft., the two upper stories about 15 ft. each. There is a lift 10 ft. by 16 ft. 8 in., which makes the handling of automobiles on the upper floor easy both for storage and repair purposes. The first floor will of course be used entirely for machines which are in daily use. By reference to the plan it will be seen that the building is L shaped. The lot has a width of 50 ft. in front, while the L is 32 ft. 6 in. wide. The depth is 100 ft.

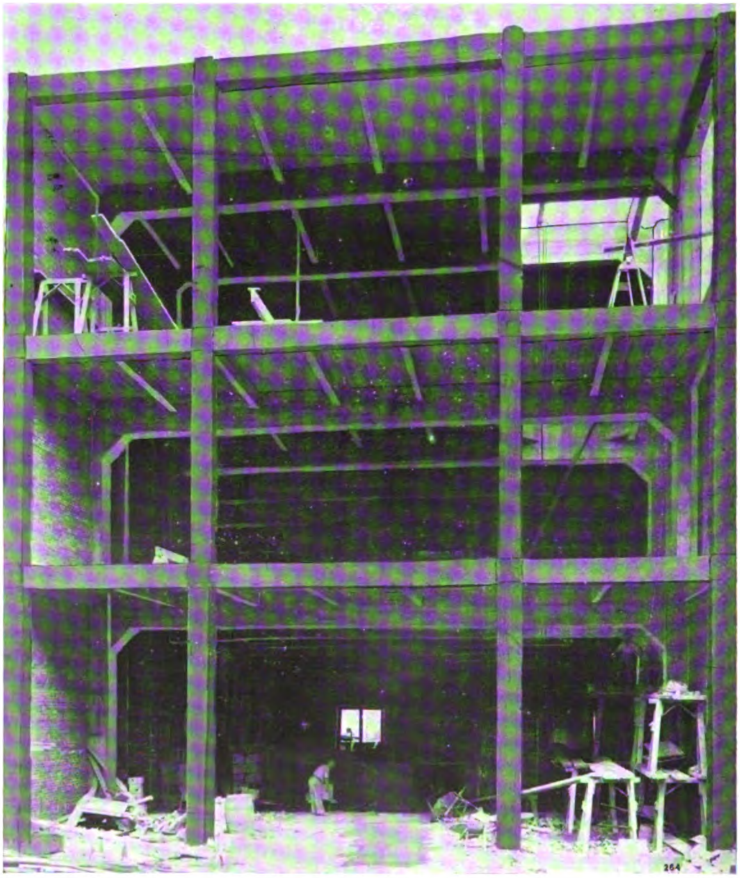


REINFORCED CONCRETE MOTOR GARAGE AT NEW YORK, U.S.A.
Elevation and ground floor plan.

The exterior is simple in design, with solid piers running up the front, with large windows between. There is a large central entrance, 16 ft. wide and of about the same height. On the first floor, on one side of the central entrance, is the office, a room about 14 ft. square, back of which is a spiral stairs leading to the other floors. Opposite this is a room of similar dimensions, which will be used as a club room. At the rear of the building is the elevator before referred to, and at one side of this is a washing stand about 20 ft. square. The second floor is intended for storage. The L on this floor is fitted up as a locker room.

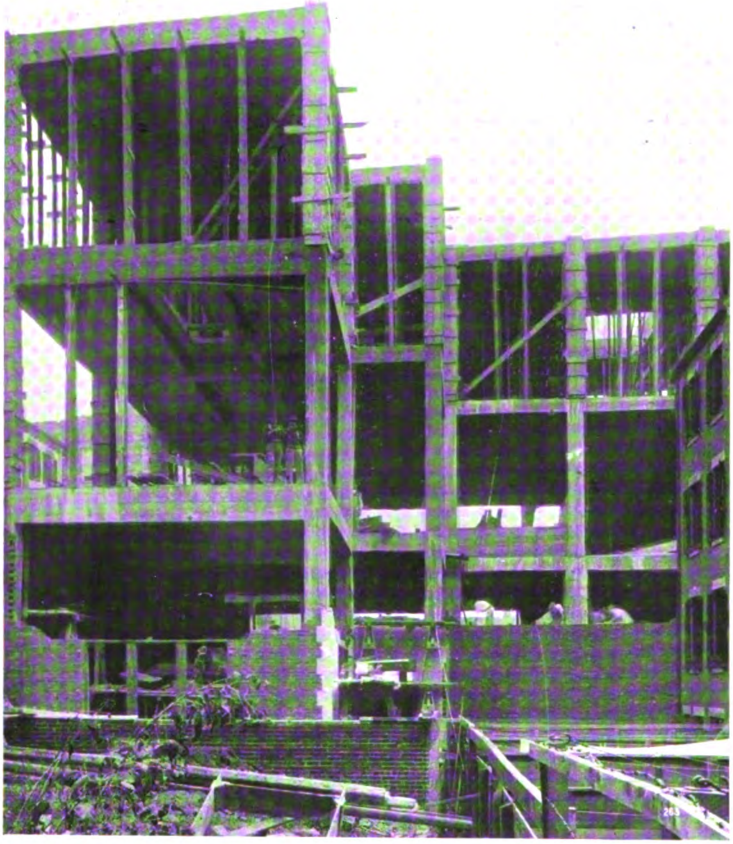
The repair department is on the third or top floor, which is lighted by a central skylight. There is a complete machine shop and all appliances necessary for the repairs of an automobile, including an electrically lighted pit for working below the machines. Although there are only three stories, the total height of the building is nearly 70 ft., on account of the extra height of the stories.

Now to turn to the construction of the building, we come to its most interesting features. Our illustrations tell the story plainly, but a short description will aid matters and give an idea of the proportions of the construction. The frame or skeleton of the building is of reinforced concrete, which works in the same manner as a steel construction. The piers and girders form frames which carry the brick wall one foot thick as panels. This method may be seen by some of the illustrations. The piers in the side walls are 26 in. square, while the piers across the front, in the wing, and about the elevator shaft, are 18 in. square. There are a few smaller columns, 16 in. by 16 in., and one that is 34 in. by 34 in. This last is at the angle of junction between the wing and main structure, and is built heavy on account of the extra number of girders attached to it. These are the dimensions



REINFORCED CONCRETE MOTOR GARAGE AT NEW YORK, U.S.A.
Front during construction, prior to facing.

at first floor level. The sizes diminish slightly as they reach the upper floors. The proportions of the girders vary with the width of the span. The greatest span is across the front section of the building, where the width is 50 ft. Thus the concrete beams cross without any central support on the upper floors. In the basement, however, there are pillars indicated in the plan at C C, etc., which carry the floor of the first story. There, of course, they do not interfere with the movements of the cars. The piers and girders average about 13 ft. 6 in. apart on centres, while the smaller transverse beams which support the floor are about 7 ft. on centres. On the top floor a reinforced girder runs completely across the front, which supports the terra cotta ornament of the cornice and the flag pole. The reinforcement is accomplished by using a rather light bar or bond perforated at intervals, and also a plain bar about $\frac{1}{4}$ in. square. There are about sixteen of these bars in one of the 18 in. piers. The method of building the concrete work is shown in several of the illustrations. Wooden boxes are made of desired size. In these the bars are set properly spaced, and then the whole is filled with an easily flowing mixture of concrete. The architects were Messrs. Snelling and Potter.—*From the "Builders' and Architects' Magazine," U.S.A., April,* 1906.



REINFORCED CONCRETE MOTOR GARAGE AT NEW YORK, U.S.A.
Back view of work in course of construction.

NEW USES FOR CONCRETE

AT HOME AND ABROAD.

Under this heading reliable information will be presented as to new uses to which concrete and reinforced concrete are put, with data as to experience obtained during the experimental stage of such new applications of these materials. The use of reinforced concrete as a substitute for timber in exposed positions is one of the questions of the moment. Railway sleepers, telegraph posts, fence posts, etc., of concrete are being tried. Similarly, efforts are at present being made to prove that reinforced concrete is an excellent substitute for brickwork, where structures of great height are required.—ED.

CONCRETE ON THE FARM.

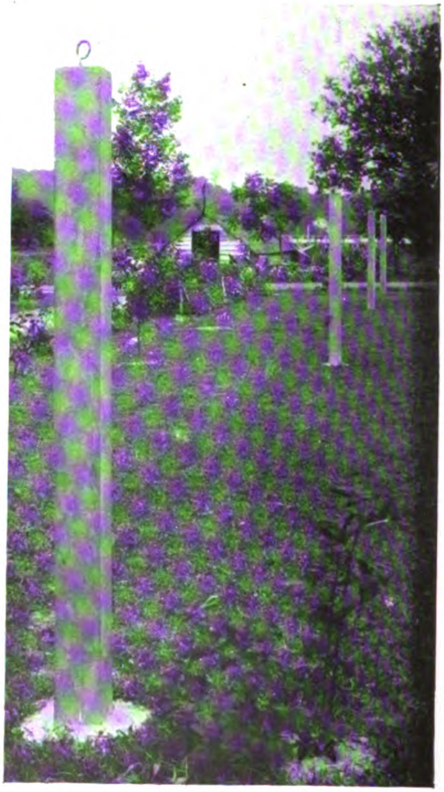
THE use of concrete for farm work, and in fact cement uses generally, have not as yet been fully realised by our farmers, and in the first place not by our farmers in a big way. In the United States, however, the great advantage of using cement concrete, concrete hollow blocks, and reinforced concrete is being rapidly realised, and it is interesting to observe how the cement trade is beginning to cater for this special market. For simple work there is no doubt that concrete has great advantages both practically and economically, particularly where there is material available for aggregate close at hand to the work to be executed, so that transportation expenses are minimised.

We thus think it might not be inappropriate to present some examples from the United States of concrete work as applied to the farm, and we would commence by illustrating a charming cowhouse at Eckerts, Pa. Of this cowhouse we show both an exterior and an interior view. Wooden partitions, wooden feeding troughs, etc., which are liable to become dirty and foul smelling, do not exist in these buildings, everything is practically of concrete.

We are also presenting a view of a concrete piggery at Gedney Farms, White Plains, N.Y., and here again, everything is built of concrete, partly reinforced by expanded metal, lathing, including all feeding troughs and bathing pools.

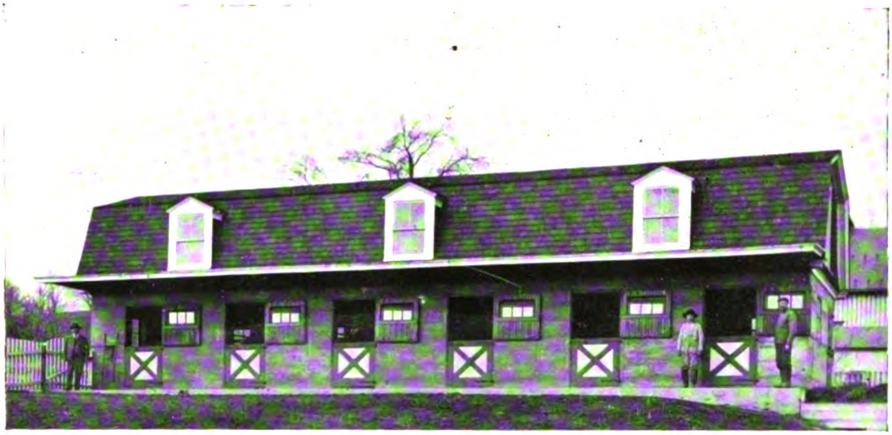
A field watering trough at Knoxville, Iowa, is illustrated; a concrete road culvert at Nantic, Ill., whilst to come to minor uses, we illustrate concrete clothes posts at Westwood, N.J., and even a horse block with hitching post from the same locality.

The big subject of fence posts we must leave for a future issue.



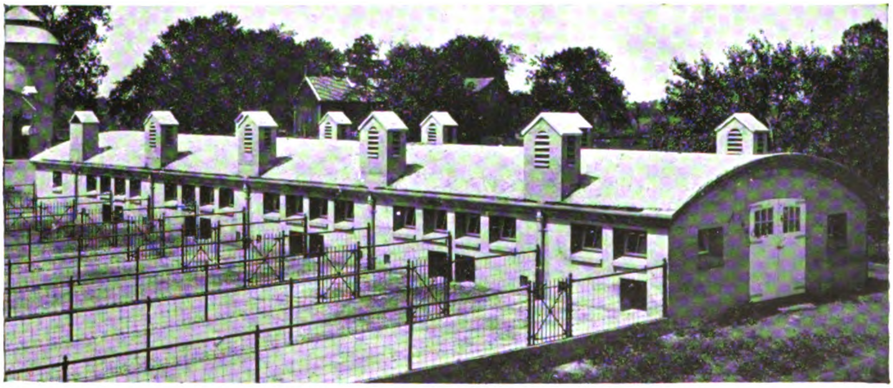
CONCRETE CLOTHES POSTS, AT WESTWOOD FARM, NEW YORK, U.S.A.

The illustrations presented will, however, indicate some of the uses to which concrete is being put on farms in the United States, and should serve as an



Concrete Cow House at Eckerts, Pa., U.S.A.

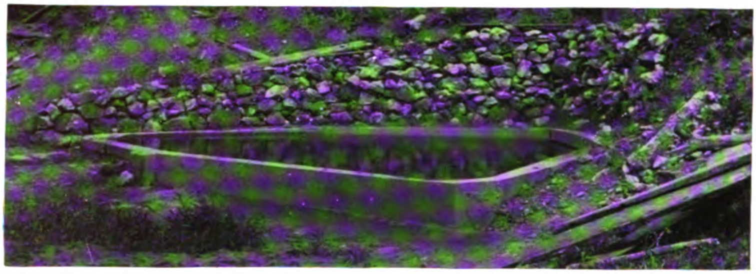
Concrete Stall Divisions at Eckerts, Pa., U.S.A.

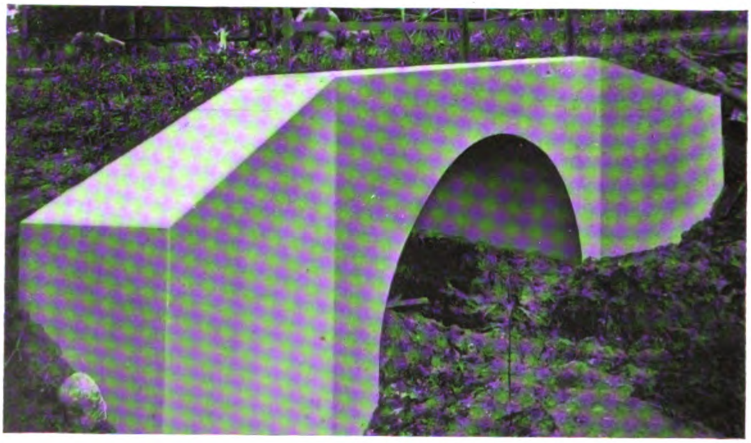


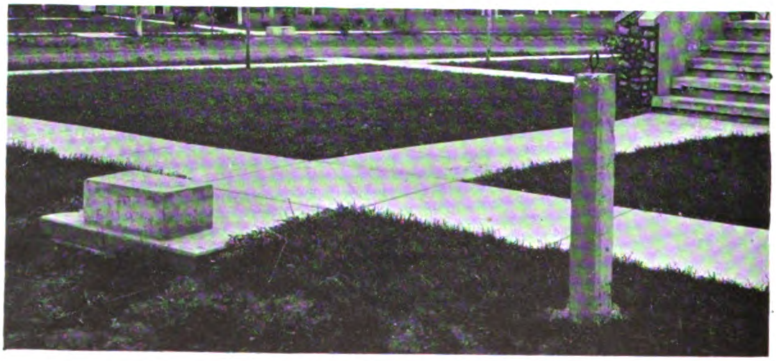
Concrete Piggery at Gedney Farm, U.S.A.

object lesson to those who are still so conservative as only to use stone or bricks and mortar, where a concrete could be rapidly and economically obtained.

The examples presented are from the *Cement Age*, where they illustrate an interesting article on the subject by Mr. E. A. Trego.


FIELD WATERING TROUGH AT KNOXSVILLE, U.S.A.


CULVERT TO FARM ROAD AT NANTIC, U.S.A.


HORSEBLOCK, HITCHING POST AND PAVING, AT WESTWOOD FARM, U.S.A.

INDUSTRIAL NOTES.

These pages have been reserved for the presentation of articles and notes on proprietary materials or systems of construction put forward by firms interested in their application. With the advent of methods of construction requiring considerable skill in design and supervision, many firms nowadays command the services of specialists whose views merit most careful attention. In these columns such views will often be presented in favour of different specialities. They must be read as ex parte statements—with which this journal is in no way associated, either for or against—but we would commend them to our readers as arguments by parties who are as a rule thoroughly conversant with the particular industry with which they are associated.—ED.

REINFORCED CONCRETE CHIMNEYS.

By J. Cargill.

In the previous issue (p. 229), a detailed description will be found of the world's highest reinforced concrete chimney of the United States, but what is more important, the descriptions were given of reinforced concrete chimneys nearer home, namely, the one for Messrs. Abram Lyle and Sons, Ltd., refiners, Plaistow Wharf, Victoria Docks, London, and for the Associated Portland Cement Manufacturers, Ltd., at their Knight Bevan and Sturge Works, Northfleet, Kent.

In the preceding article we were able to show the first Weber concrete chimney in course of construction for Messrs. Lyle, and the view on page 230 showed this chimney some 80 ft. above the ground.

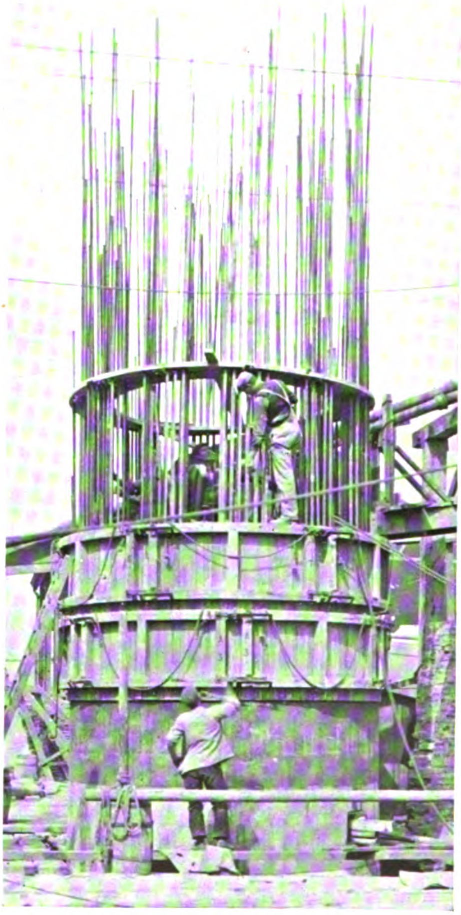
In the current issue, there will be found three illustrations of the Northfleet chimney at its foundation stage, as we are under the impression that detailed technical illustrations of this description must be of interest to the members of the technical professions generally. This is the second reinforced concrete chimney being built in Great Britain. Whilst the Lyle chimney was 261 ft. high with a flue of 20 ft. in diameter, the Northfleet is 247 ft. high with a flue of 8 ft. 6 in. diameter.

Both chimneys, as we have indicated before, are designed to meet the wind pressure equivalent to a velocity of 110 miles per hour.

In pointing to these examples, both of which were constructed by the Weber Steel-Concrete Chimney Company, Ltd., of Queen Anne's Chambers, Westminster, we are naturally proud to be able to show work that is being executed for two well-known firms, when the idea of having reinforced concrete chimneys in this country is only some three months old.

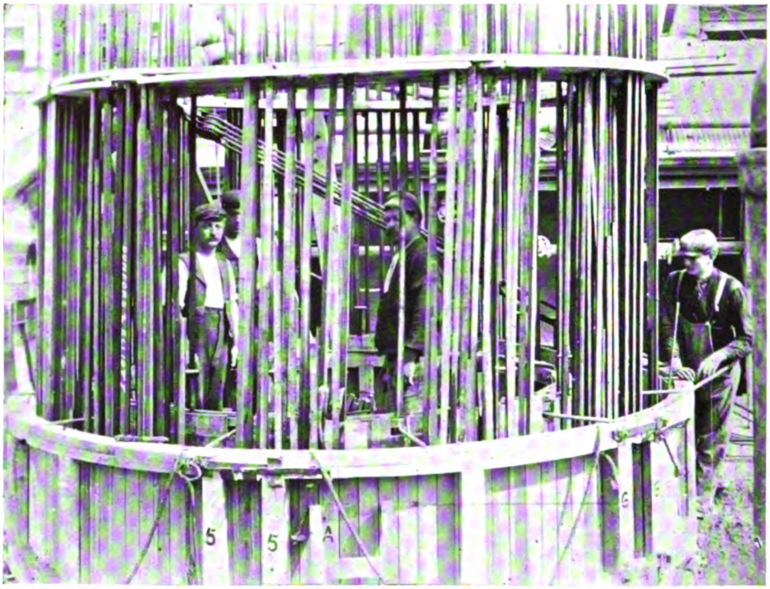
Their Advantages.

Among the advantages claimed for the concrete chimney is lightness of weight, thus conserving space or area necessary for a proper foundation. They are lighter in weight than self-supporting steel chimneys,

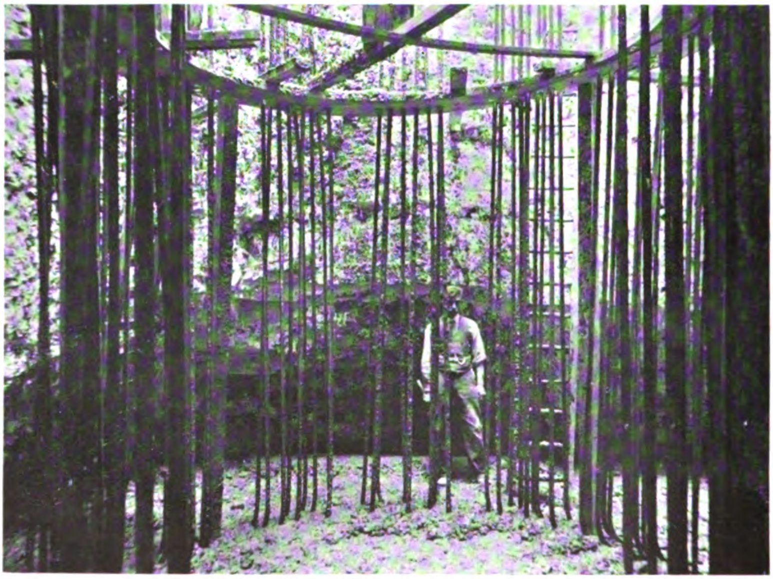


THE NORTHFLEET REINFORCED CONCRETE CHIMNEY.

including lining and foundation. The pressure on ground is from one-fifth to one-third that of a brick chimney. This is an advantage of the highest importance where the ground has a limited carrying capacity, necessitating piles or other foundation work of a special character which would increase the total cost of the chimney.



(Ground level.)



(Foundations.)

THE NORTHFLEET REINFORCED CONCRETE CHIMNEY.

Reinforced concrete chimneys occupy a much smaller area than brick chimneys. Their foundations require about from one-fourth to one-third the area of a brick chimney of the same diameter of flue and height. This saving of space is often an advantage of the greatest importance.

These chimneys, designed upon correct theoretical principles, are absolutely monolithic in character, being one solid single piece of stone from bottom to top. There are no mortar joints in their construction to permit leakage of air into the flue, which is detrimental to draught and economy; they are absolutely air tight.

The surface of the flue being smooth, minimises frictional resistance to the flow of gases and so ensures a higher efficiency than that of any other chimney.

They are erected in a shorter time than other chimneys, as there is no waiting for moulding and firing of purpose-made bricks. Steel, British Portland cement, sand and gravel are quickly obtainable in any locality.

"VULCANITE" ROOFING FOR CONCRETE FLATS.

By H. Cates.

WITH the growing tendency to employ flat concrete roofing, not only upon the utilitarian buildings of the factory type, but also the first-class town property, and even the residential and cottage property, the problem has necessarily arisen to obtain a covering that is not only absolutely waterproof at the outset, but will permanently remain so, irrrespective of changes of temperature and irrespective of small settlements or cracks. Such a covering, it is claimed, and we hold rightly claimed, has been found in the Vulcanite roofing, a form of patent roofing, applied by Messrs. Vulcanite, Ltd., of No. 118, Cannon Street, London, E.C., and of Laganvale, Belfast.

This patent roofing has been employed in Great Britain for some ten years upon buildings varying in expense from £500 to £100,000 in public and private ownership, the roofing supplied to the War Office alone aggregating over 150,000 square feet.

Although perhaps not as well known as it might be, this Vulcanite roofing has long passed the experimental stage, and, in fact, has already been employed in a less perfect stage abroad, some fifty years before the improvements embodied in the patents under which the work is now being executed.

No Cracks or Fractures.

The cracks and fractures which so frequently occur in asphalte upon the slightest settlement, or upon the expansion of the concrete, or even upon the vibration of machinery, do not, in fact cannot, occur with Vulcanite roofing owing to its permanent elasticity. How highly it is thought of may be gauged from the fact that even the President of the Royal Institute of Architects, Mr. John Belcher, A.R.A., has used it for the Royal London Friendly Society's purposes in that monumental building in Finsbury Square, London, which has a roof garden covered with patent Vulcanite Roofing and a roof tank holding 5½ ft. of water.

Roof Water-Tanks.

And here, with the growing tendency, more particularly in factories, to utilise the roof surface as a water tank, for the dual purpose of having an ample water supply for fire purposes and an equal temperature on the upper floor of the building, we would point to an example illustrated herewith of a roof tank at Brixton which holds permanently 2 ft. of water and measures 86 ft. by 25 ft., and in this case the roof tank is actually not even on a concrete roof but on boards supported by wood joists, which is, of course, a very popular form of applying it where economy precludes the application of a concrete flat.

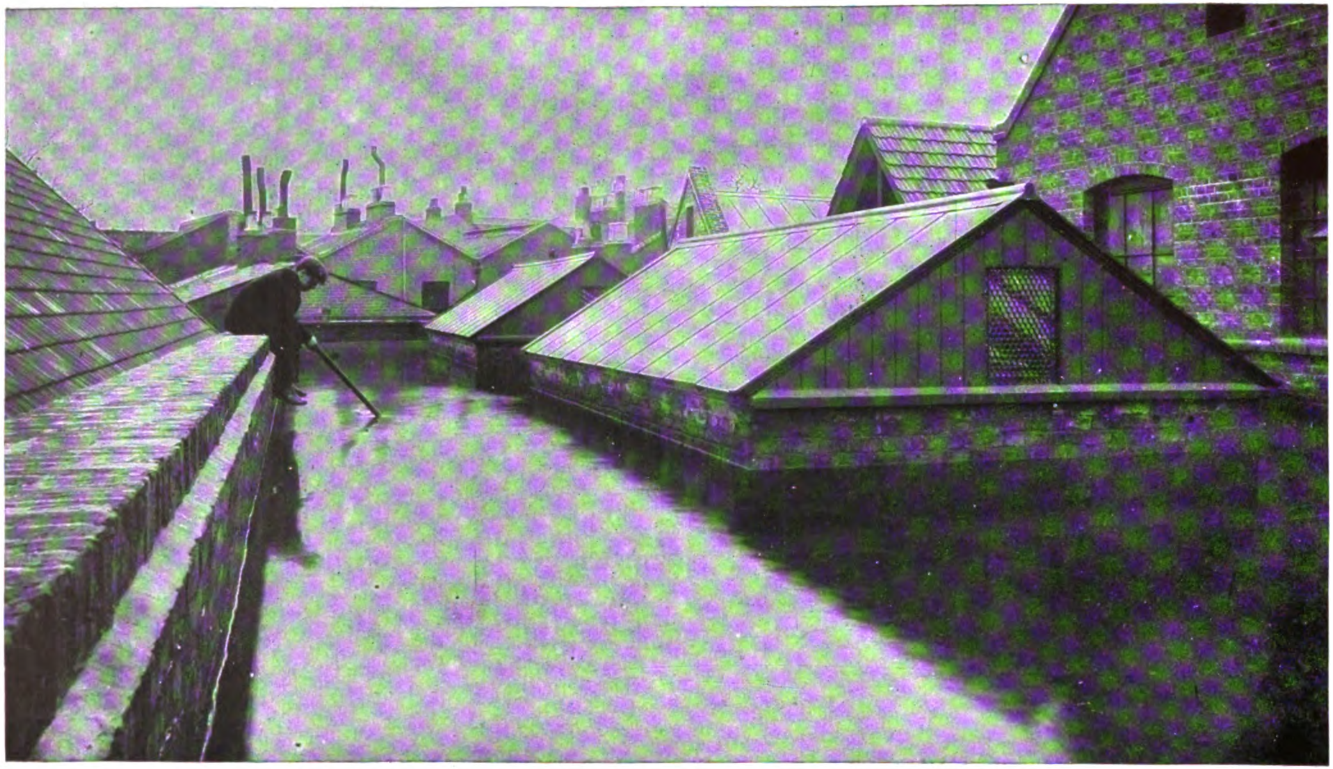
It would lead too far to quote examples, but a well illustrated catalogue of 56 pages has been recently issued by Messrs. Vulcanite, Ltd., which, besides containing many examples, presents the working details, and we should recommend those interested in this important subject to apply for copies.

With this growing popularity of the concrete roofing, this question of roofing material should certainly be of interest to every architect, constructional engineer, surveyor and contractor.

Roofs to Projecting Shops.

Referring to its application more particularly in the Metropolis, an announcement has been made by the London office of Vulcanite, Ltd., that this roofing is now easily available for the covering of the roofs of the many projecting shops which have to be modernised under the requirements of the recent Building Act, and to those who would desire to comply with this requirement of the Act at the least possible outlay, and with the least possible inconvenience, we would strongly recommend the existing roof or flat being simply left in position to serve as centering to the new concrete flat, strengthened, perhaps, with the simple network of iron bars or metal lathing, the whole to be covered with Vulcanite roofing, which will then make the flat above the projecting shop not only water-tight, air-tight and proof against slight settlements, cracks, and the like, but will give the occupier a surface that can easily be used as a roof garden, gravelled and pleasantly arranged for recreation and the like.

The roofing complies in every respect with the London Building Act and with the requirements of the insurance companies; and as it appears favourable in price, and has other advantages, it certainly calls for attention in this respect.



Roof Tank at Brixton.

86 ft. by 25 ft. to hold 2 ft. of water, so after deducting area of lantern lights, will hold about 100 tons of water. Constructed on wood joists and boarding, with brick walls, and is over a stable.

(George A. Lansdown, Architect.)

ARTICLES AND PAPERS

AT HOME AND ABROAD.

The following articles and papers are among the most important published at home and abroad during June and July of 1906:—

I.—CONCRETE CONSTRUCTION.

Articles.

THE CROSS RIVER DAM IN THE CROTON WATERSHED: an unusual method of construction is being employed in the Cross River dam, now being built to form a reservoir for the storage of about nine million gallons of water, in the Croton watershed. This dam has a total length of about 900 ft. at the crest, and a maximum height of 164 ft. from the lowest point in the foundations to the crest of the dam. The body of the dam is of cyclopean concrete, faced on both upstream and downstream surface with large cast blocks of concrete, very little cut stone being used in the structure. It is estimated that the substitution of concrete blocks for cut stone will result in a saving of over £40,000. At the south end the dam terminates in an earthen embankment with a concrete core. At the north end, it terminates in an abutment with a circular bastion of 30 ft. diameter, containing a storage chamber of 20 ft. diameter, and about 9 ft. deep. Beyond the bastion, the structure is continued with a waste weir, having its crest 10 ft. below that of the main dam. The weir, built of monolithic concrete, is reinforced with vertical 1 in. twisted steel rods, 5 ft. 6 in. apart, and has a total length of about 240 ft. to provide for a flow, greater than that of the Cross River in heaviest freshets. A 31 ft. by 21 ft. 9 in. gate house is located near the north end of the upstream face of the dam, and is built of cyclopean concrete with plain surfaces, the outer walls being 6 ft. thick. Both sides of the dam are faced with moulded concrete blocks laid with headers and fillers. The stretchers are 8 ft. long and about 3 ft. 6 in. wide at the bottom, the headers are 30 in. long, parallel with the face of the dam, and about 7 ft. wide, perpendicular to it. The maximum weight of the blocks is about six tons each, and the specification demands that they shall be at least three months old before being laid.—*Eng. Rec.*, 16.6.06.

STRAUSS SYSTEM OF CONCRETE PILES.—*Beton u. Eisen, June*, 1906.

CEMENT AND CONCRETE AT THE NUREMBERG EXHIBITION. —*Zement u. Beton*, 1.7.06.

II.—REINFORCED CONCRETE CONSTRUCTION.

Articles.

THE PALACE HOTEL, LUCERNE: *ill.* description of a very large hotel, mainly in reinforced concrete.—*Zement u. Beton*, 1.6.06.

REINFORCEMENT OF CONCRETE STAIRCASES. By Dr. F. von Emperger: with plate.—*Beton u. Eisen, June*, 1906.

REINFORCED CONCRETE BEAMS. Mohr-Habay System.—*Le Ciment, June*, 1906.

THE ADHESION OF CONCRETE TO STEEL: referring to the fact that while there is comparatively little adhesion between concrete and a plane surface of clean steel simply pressed upon its surface, the writer of this article states that when a round bar of steel has been embedded for a certain distance into a block of concrete, the bond between the concrete and the steel becomes very great. He then quotes the various conclusions arrived at by well-known authorities, the results serving to demonstrate the fact, that the adhesion between concrete and ordinary round steel bars may be taken with safety at about 500 lb. per square inch. Applying this value to the case of a round bar ½ in. diameter embedded for a length of 1 ft. the total calculated resistance would be $0{\cdot}5\ \pi \times 12 \times 500 = 9{,}425$ lb., and if the bar were embedded for a length of 10 ft., it would be 94,250 lb., or about seven and a half times the ultimate resistance of the ½ in. diameter bar of mild steel.—*Bldr.* 30.6.06.

A REINFORCED CONCRETE LOCOMOTIVE COALING STATION OF UNUSUAL CONSTRUCTION ON THE LEHIGH VALLEY RAILROAD. By W. E. Phelps: this station was designed to furnish coal to about 100 passenger and yard engines per day. The passenger engines generally burn lump anthracite, while the freight and yard engines burn a mixture of small anthracite and bituminous coal. The necessity for mixing some 300 tons of coal daily induced the designer to favour the platform type of coaling plant, in which the coal is dumped from the bunkers directly into locomotive tenders. At the end of the range of coal bunkers, there are a steam drying apparatus, and two sand bins, capable of storing about 850 tons of sand. The whole of the structure was built in reinforced concrete, in which about 7,000 lineal feet of ⅝-in. Ransome twisted steel bars were used as reinforcement. Owing to the large amount of excavation necessary for the approach track, which is 1,375 ft. long, about 2,000 cubic yards of retaining walls had to be built, varying in height from 4 ft. to 22 ft. The article is *ill.* by a photograph and plans showing full details of the construction.—*Eng. News*, 14.6.06.

EARTHQUAKE-RESISTING BUILDINGS: mainly a discussion of the lessons of the San Francisco earthquake, and of the advantages of reinforced concrete construction in such regions.—*Beton u. Eisen, July*, 1906.

REINFORCED CONCRETE CANTILEVER GALLERIES OF THE EVANGELICAL CHURCH, OBERHAUSEN. By R. Heim: with plate and photographs.—*Beton u. Eisen, July*, 1906.

III.—STEEL CONSTRUCTION.

Articles.

THE ELECTROLYTIC CORROSION OF STRUCTURAL STEEL. By Maximilian Toch: the electrolytic corrosion of structural steel, particularly those parts known as grillage beams supporting columns and base posts, which are either in the ground or surrounded by concrete and partly above the ground, is a question that has received considerable attention of late, and with a view to determining the pole at which corrosion occurs, and whether one pole is more active than the other, a series of experiments was conducted by the author. The results of these experiments, which are discussed fully in the present paper, are said to prove conclusively (1) that the electrolytic corrosion of structural steel, embedded in concrete or sand, takes place only at the anode where it occurs with great violence; and (2) that the cathode is protected by the electrical current. The popular impression that cement is a protection against corrosion of all kinds, is said to be fallacious, for the anode not only rusts very violently, but a molecular increase of volume may take place which will split the concrete shell. Another conclusion arrived at is, that the electrolytic rusting of grillage beams in buildings need not be feared if the structural steel be protected by a good insulating material; but the insulating medium should form a bond with the concrete.—*Eng. Rec.* 30.6.06.

IV.—MATERIALS, TESTS, AND FORMULÆ.

Articles.

Influence of the Addition of Chemical Substances on the Resistance of Portland Cement.—*Il Cemento June*, 1906.

Welding of Steel Rods in Reinforced Concrete Work. By C. Guidi.—*Il Cemento, June*, 1906.

Calculation of Reinforced Concrete Sills for Moist Foundations. By Prof. Ramisch, Breslau.—*Zement u. Beton*, 1.6.06.

Empirical Formulæ for Reinforced Arches. By Daniel B. Luten: recognising the fact that reinforced concrete arches are proving deservedly popular, on account of their durability, handsome appearance, and economy, as compared with other bridge structures, the writer points out that their efficient design remains an enigma to the busy engineer. In this article, a method of empirical design is stated, with the object of enabling a designer to lay off all the details of the section, for an 80 ft. span, in less than an hour's time, yet with great accuracy and efficiency. It is claimed that the method has been applied to upwards of 100 arches, with spans ranging from 5 ft. to 100 ft., not one of which has shown any signs of weakness. In order to obtain these formulæ, the writer noted the results furnished by tests upon various model arches, with and without reinforcement, and under various conditions of loading and construction. The formulæ are as follows:—

(1) *To determine the curve of intrados.*—Draw an ellipse of the required span and rise. Pass a segment of a circle through the crown and springings of the ellipse. Bisect the vertical ordinates between the ellipse and the circle. Approximate the resulting curve by arcs of circles, adjusting the curve at the springings, to become tangential to the verticals.

(2) *To determine the crown thickness.*

$$C = \frac{3\,S^2\,(R + 3F)}{4{,}000R - S^2} + \frac{U\,S^2}{30{,}000R} + \frac{L(S + 5R)}{150R} + 4$$

(3) *To determine the curve of extrados.*—The curve of the extrados is a segment of a circle of radius $E = I + \frac{C}{5}$.

The extrados circle should be produced to its intersection with the abutment ties produced, but if such intersection does not occur within 75 deg. of the crown of the extrados circle, then the back of the abutment is determined by a tangent to this circle, having a batter of one in four.

(4) *To determine the diameter of the abutment ties.*

$$P = \frac{1}{5}\sqrt{D\,(2C - H)}$$

(5) *To determine the diameter of the arch-rods.*

$$A = \sqrt{D\,\frac{SL}{250C}}$$

where C = crown thickness in inches.
S = span in feet.
R = rise from springings to crown in feet.
F = fill over crown of extrados in feet.
H = height of opening from pavement to crown in feet.
U = uniform liveloading in pounds per square foot.
L = moving load that will be concentrated on single track or single roadway, over entire span in tons, of 2,000 lb.
E = radius of extrados in feet.
I = radius of intrados at crown in feet.
P = diameter of abutment tie in inches.
A = diameter of arch rod in inches.
D = distance between rods in feet.

The writer concludes by giving the application of these formulæ to the design of an arch of 80 ft. span.—*Eng. News*, 28.6.06.

Calculation of Resistance of Concrete Columns to Bending. By Prof. G. Ramisch, Breslau.—*Zement u. Beton*, 1.7.06.

The Comparative Advantages of Hard and Soft Steel for Reinforcing Concrete. By Danel B. Luten: among designers of reinforced concrete structures, two factions appear to have arisen, one advocating the use of hard steel having an elastic limit of 55,000 lb. to 60,000 lb. per square inch, the other favouring soft steel, with an elastic limit of 35,000 lb. to 40,000 lb. per square inch. The following advantages are claimed for hard steel: (1) Greater efficiency; (2) less liability of the concrete to crack; (3) cheaper quality of steel, and (4) greatly increased factor of safety. For soft steel the advantages claimed are as follows: (1) Greater reliability; (2) material more easily obtainable; (3) material readily workable, and (4) increased adhesive surface. The writer discusses these various points in detail, and finally arrives at the conclusions that if hard steel and soft steel are readily procurable of reliable quality at the same cost, neither possesses any marked advantage over the other for reinforcement, and that steel of any usual elastic limit may be used in properly designed structures, without reference to its percentage of carbon.—*Eng. News*, 19.7.06.

SOME SUBJECTS DEALT WITH IN No. 2.

Reinforced Concrete in the United States	Capt. Sewell, U.S.A.
Reinforced Concrete Piles in Tidal Waters	A. T. Walmisley, M.Inst.C.E.
Reinforced Concrete on the G.W.R.	W. Armstrong, M.Inst.C.E.
Hollow Concrete Block Building	S. B. Newberry, Cleveland, U.S.A.

The R.I.B.A. and Reinforced Concrete—Fictitious Portland Cement—The Merchandise Act—Reinforced Concrete Roofs in Egypt—A Reinforced Concrete Bridge at Indiana, U.S.A.—Water Tower at Bournemouth—Flow of Concrete under Pressure—Fire Tests with Reinforced Concrete—Loose Stirrups *versus* Rigid Shear Members in Reinforced Concrete Beams.

SOME SUBJECTS DEALT WITH IN No. 3.

The Historical Evolution of Reinforced Concrete in France	N. De Tedesco.
Reinforced Concrete Bridges.—I.	W. N. Twelvetrees, M.Inst.M.E.
The Setting of Portland Cement.—II.	E. Candlot (Paris).
Reinforced Concrete Water Mains	R. H. Wyrill, M.Inst C.E.
The Theory of Reinforced Concrete	Captain Sewell (U.S.A.).

Recent Examples of Steel and Concrete Buildings in Scotland—Types of Hollow Concrete Blocks used in the States and their Patents—Concrete Ribbed Arch Footbridge over a Gorge—Reinforced Concrete Water Tower, Champagne-Sur-Seine, France—Reinforced Concrete Towers for Power Transmission Lines—Fire Tests with Reinforced Concrete Floors.

CONCRETE & CONSTRUCTIONAL ENGINEERING

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IMPORTANT ARTICLES.

The following, among others, are kindly contributing Articles:—

W. H. HUNTER, M.Inst.C.E., Chief Engineer, Manchester Ship Canal.

CHARLES F. MARSH, M.Inst.C.E., M.Inst.M.E., Author of "Reinforced Concrete."

EDWIN O. SACHS, F.R.S.Ed., Architect.

Captain SEWELL, Corps of Engineers, United States Army.

JAMES SHEPPARD, Surveyor, North British and Mercantile Insurance Company.

W. NOBLE TWELVETREES, M.Inst.M.E., Author of "Concrete-Steel."

A. T. WALMISLEY, M.Inst.C.E., Engineer, Dover Harbour Board.

Lieut.-Colonel J. WINN, R.E., Author of "Notes on Steel-Concrete."

R. H. WYRILL, M.Inst.C.E., Waterworks Engineer, Swansea.

The following, among others, are kindly presenting occasional contributions on the Setting of Portland Cement:—

H. K. G. BAMBER, F.C.S.

D. B. BUTLER, A.M.Inst.C.E., F.C.S.

Dr. W. MICHAELIS (Berlin).

CECIL H. DESCH, D.Sc., Ph.D.

H. HOWARD HUMPHREYS, M.Inst.M.E.

N. DE TEDESCO (Paris).

RICHARD L. HUMPHREY, M.Am.Soc.C.E. (Philadelphia).

SOME SUBJECTS DEALT WITH IN No. I.

The Advent of the Concrete Age	LIEUT.-COL. E. A. WINN, R.E.
Steel Skeleton Construction and the London Building Acts	W. NOBLE TWELVETREES, M.Inst. M.E.
Reinforced Concrete Construction	CHARLES F. MARSH, M.Inst.C.E.
The Setting of Portland Cement	CECIL H. DESCH, D.Sc.
The Preservation of Iron and Steel	B. H. THWAITE, C.E.
Reinforced Concrete at Munich (The New "Tietz" Stores)	

Impending Conferences on Reinforced Concrete—The Fire Resistance of Concrete—Fictitious Portland Cement—Safeguards against Freezing in Concrete Construction—Concrete Railway Sleepers in U.S.A.—New York Rules on Reinforced Concrete—German Portland Cement Manufacturers—A Reinforced Concrete System with Rigid Shear Members.

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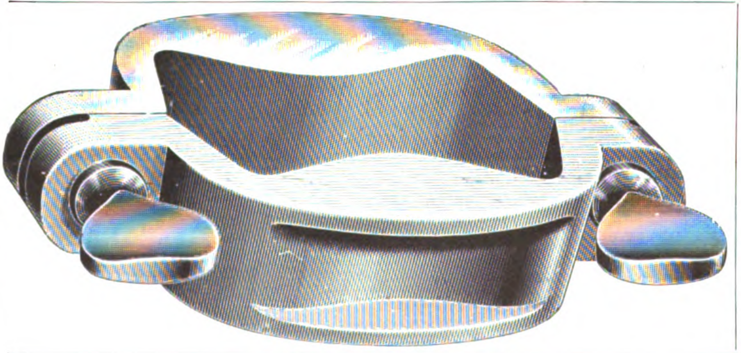

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CONCRETE
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Volume I. No. 5. NOVEMBER, 1906.

EDITORIAL NOTES.

THE INTERNATIONAL TESTING ASSOCIATION.

THE International Testing Association met at Brussels in September, and the Conference was a most successful one, both technically and socially. The work was, as usual, divided into three sections, the one dealing with metals, the second with cement and mortars, and the third with miscellaneous materials. The papers presented in all three sections were of a very high standard, and the debates were of a most useful description, the success of these discussions being mainly due to the excellent arrangements by which all papers had been circulated six weeks in advance of the meeting. The only regrettable feature of the conference was the small attendance from Great Britain and the United States, for all the continental countries were exceedingly well represented.

It would be premature to publish the resolutions arrived at until they have been officially issued, for in resolutions of a conference of this description the exact wording is essential, and, therefore, the presentation of even their general tenour would scarcely be in place. We think, however, that we should not be indiscrete in indicating that one of the resolutions unanimously adopted was the formation of a special commission to deal with reinforced concrete, the primary work of this commission being to collect data as to testing methods and results of tests, and to further obtain records as to failures of reinforced concrete. It is intended that the lessons of this preliminary work shall then be applied at the next conference for the drafting of a programme of any research work still necessary. The next conference, by the bye, will be held at Copenhagen.

THE NEW FRENCH RULES AS TO REINFORCED CONCRETE.

SINCE years all those interested in the development of reinforced concrete have been anxiously awaiting the pronouncement of the French Ministry of Public Works as to reinforced concrete, and there has been a considerable difference of opinion as to the nature of the rules that might be expected.

It is with the greatest possible pleasure that we present in the current number a translation of what we believe will be the exact wording of the rules just about to be issued by the French Government on reinforced concrete. These rules, we understand, have now passed through all the stages of special commissions and departmental inquiries, and are actually in the Government printers'hands, so that it may be fairly anticipated that they will be published in the form indicated, and that any alterations will be but slight. It is not very often that

VARIOUS CONCRETE

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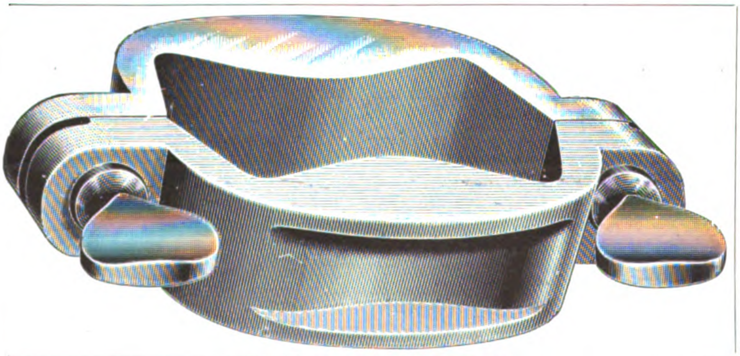

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THE NEW FRENCH RULES AS TO REINFORCED CONCRETE.

SINCE years all those interested in the development of reinforced concrete have been anxiously awaiting the pronouncement of the French Ministry of Public Works as to reinforced concrete, and there has been a considerable difference of opinion as to the nature of the rules that might be expected.

It is with the greatest possible pleasure that we present in the current number a translation of what we believe will be the exact wording of the rules just about to be issued by the French Government on reinforced concrete. These rules, we understand, have now passed through all the stages of special commissions and departmental inquiries, and are actually in the Government printers'hands, so that it may be fairly anticipated that they will be published in the form indicated, and that any alterations will be but slight. It is not very often that a technical journal can present information of this description in advance of official publication, but, as a matter of fact, we consider the subject matter of these rules to be of such high importance that we have spared no pains to obtain the final version, so that it may serve at the earliest opportunity as a guide to those who are formulating similar rules and regulations in other countries, including our own.

It is not our intention at this stage to comment upon the rules, or upon the highly instructive circular that will be issued with them; but we present them as a most valuable contribution to the subject, and would add that the technical professions of all countries should be eminently indebted to those who have been working for the last five years to formulate the code referred to.

In conclusion we may say that the French text has been translated specially for us, and revised under the best available authority. The copyright, too, has not only been taken out in this country, but also in the United States of America.

FICTITIOUS "PORTLAND" CEMENT.

An article by a cement maker will be found in this issue, in which a recent report by our Consul-general at Antwerp is referred to in detail. The importation of fictitious "Portland" cement into this country from Belgium has long been a menace to sound building construction, and we cannot sufficiently warn either building owners, architects, engineers and contractors against the danger of employing such unreliable material. As to the regrettable state of affairs which allows fictitious "Portland" cement to pass our Customs, and to be sold in Great Britain with English marks and initials, little can be added that we have not said before; but all concerned should certainly be on the alert against the use of this spurious material, and be prepared for its presentation on the works in all manner of forms, with fictitious labels, bogus marks, and the like.

Perhaps we should add that the latest collapse of a reinforced concrete building recorded is again due to the use of fictitious Belgian "Portland" cement, hailing from Antwerp, and we have full details of the case before us.

CONCRETE IN EVERYDAY USE.

Our recent article on the uses of concrete on the farm seems to have been received with interest far wider afield than we had anticipated; great landowners, estate stewards, agents, and others have not only been applying for our previous issue, but have been requesting us to present particulars as to the uses of concrete in agricultural buildings. The increasing cost of timber, the anxiety as to its maintenance, and the worry of its constant re-instatement, is a matter of serious importance to all who have to deal with country property. In the current issue, in response to the requests received, we are presenting particulars from the United States as to the erection of concrete fence posts, and we are sure that there are many districts where the application of such concrete fence posts will not only be found most useful, but very economical, more especially where the necessary aggregate is easily obtainable, and where Portland cement can be procured without great expense for carriage.

CONCRETE AS A FIRE RESISTANT IN THE UNITED STATES.

WHILST France was the pioneer in the application of reinforced concrete, and Germany closely followed suit, it is interesting to remember that the advent of this system of construction into ordinary building practice in the United States was by no means rapid, and that it met with considerable opposition.

An eminently interesting leading article in the *Engineering News* recently deals with the use of reinforced concrete as a fire resistant. Summarised, *Engineering News* says that it was not until 1896 that a serious attempt was made to introduce concrete at all for floor construction in fire resisting buildings in New York, much less reinforced concrete, and that almost a ban was laid upon it at the time by many influential officials of the building department, as also by the powerful contracting world which was closely connected with the clay "fire-proofing" trade.

A bitter fight resulted, the outcome of which, however, was the withdrawal of the official bann, not only in New York, but practically all over the United States. Unfortunately, this withdrawal did not moderate the animosity of the rival business interests towards each other, an animosity which, however, did not damage the position of concrete as a fire-resisting material, it being now generally used in the United States, and universally recognised as an excellent "risk" by the Fire Insurance Companies.

What is, however, still more curious, is a point on which the *Engineering News* article does not touch, namely, that the clay interests are gradually but surely changing their practice, if not their views, and we find that the leading exponents of the clay "fire-proofing" industry in the United States now carry out important works of reinforced concrete and clay combined, in which the so-called terra-cotta "tile," although not actually confessed, plays a very minor part.

It would almost remind us of the state of affairs in the metropolis, where, for all practical purposes, some of the older "fire-proofing" firms, who were originally strong opponents of concrete work, are gradually but surely entering the field of concrete construction, and equally gradually giving quite a second place to their earlier terra-cotta systems of construction.

We are the last not to fully realise that, for certain purposes in floor construction, the porous terra-cotta lintel may be useful and economical; but generally speaking concrete is found to be more practical and constructionally more sound, and, all things considered, less costly. As to dense terra-cotta for floor construction or the protection of metal work, its application is scientifically and practically wrong; in fact, dense terra-cotta is distinctly dangerous from the fire point of view. How it comes still to be used in this age of progress in our metropolis can scarcely be understood, were it not for the fact that bad habits die hard, and private interests sometimes require consideration. The complete disappearance of the dense terra-cotta in floors and protective coverings intended to be fire-resisting is, however, only a matter of time.

A RECENT FIRE TEST.

WE referred in our previous issue to the fact that a reinforced concrete floor, in which "indented" bars were used, had obtained official classification as being fully protective (Class B), after having withstood a fire test of four hours, at temperatures of and over 1800 deg. F., the fire being immediately followed by the application of water for five minutes, and the load being 2½ cwt. per ft. super. We now have the British Fire Prevention Committee's official report before us, and we observe that the 15 ft. beams in this floor only deflected ¾ in. This we hold to be a very interesting result indeed, for it throws considerable light upon the value of having a mechanical bond in reinforced concrete floors, as far as the question of fire resistance is concerned. We await with interest the continuation of this important series of fire tests with floors, so that the respective values of the different forms of construction, and the various bars applied, may be accurately gauged from the fire point of view.

VENICE UNDER REPAIR.

A RECENT article under this heading has been published in the *Morning Post*, and includes some interesting particulars as to the foundations of the Campanile, and the criticisms which are being directed locally against the use of Portland cement in preference to puzzolana. We have discussed this matter of the Campanile foundations with several valued contributors, who recently had an opportunity of inspecting them, and they are certainly under the impression that Portland cement was alone used below the level of the St. Mark's Square, practically entirely under water, while puzzolana was employed above the level of the square. Whether Portland cement was used below or above ground, the Venetian architects may be satisfied that if the cement was of really first class quality they need have no fear of its durability. The whole crux of the matter, of course, rests with the nature of the Portland cement used, but our friends mention the names of certain makers whose cement they believe to have been employed, and we see no reason why there should be the slightest doubt as to its reliability.

As to the heading "Venice under Repair," in its more general aspect, the whole of Venice will unquestionably have to be put on to new foundations soon, and concrete or reinforced concrete piles must take the place of the timber piles now in use. Curiously enough, we have not yet been able to trace any reinforced concrete piling at Venice, although we have some across come reinforced concrete slab foundations, and a large reinforced concrete silo in course of construction on a kind of tank foundation.

The Historical Evolution of Reinforced Concrete in Germany.

By O. KOHLMORGEN,
Government Surveyor, Berlin.

Although we generally look upon France as the pioneer country for reinforced concrete work, Germany, as a matter of fact, takes the lead among Continental countries in the application of this form of construction on sound business lines.

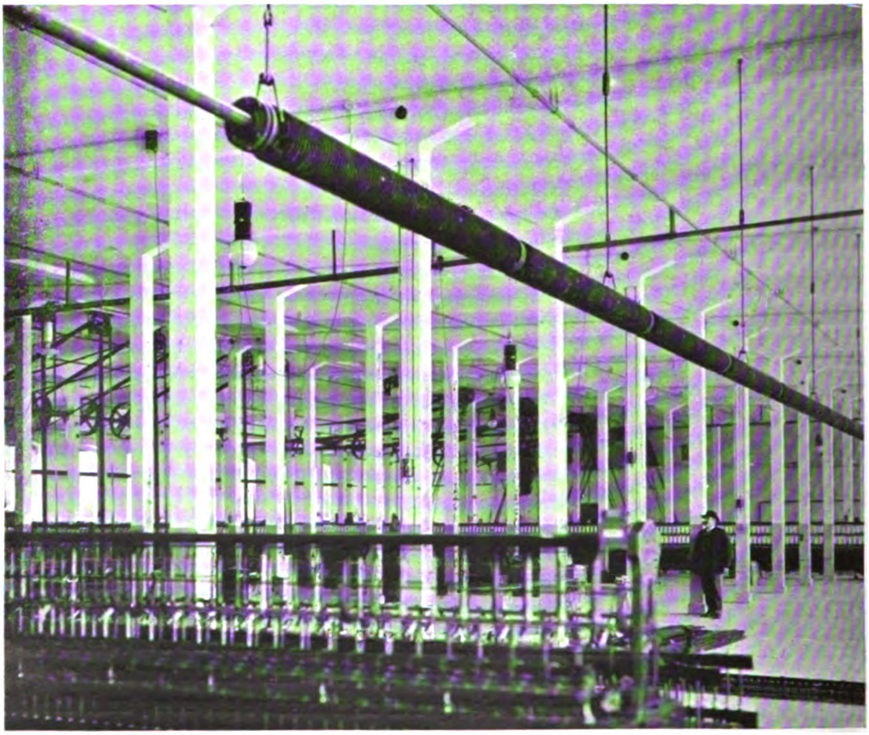
Although originally subject in no small degree to the "system" put forward by Monier and his German collaborators, there is no country at present where the evolution of reinforced concrete has been less subject to patent claims or less influenced by the system monger. Reinforced concrete construction has long been recognised in Germany as a method of construction open to all comers, and patent rights have been limited—as they should be—to particular improvements in bars, stirrups, appliances for facilitating work and the like. Every civil engineer in Germany, and many architects too, will undertake to design reinforced concrete structures on commonsense lines, applying such specialities as improved patent bars, shuttering, etc., as they deem fit, much as a sanitary engineer lays out his scheme of construction and then selects his patent traps, and other appliances.

Thus reinforced concrete construction is available to every building owner on the most economical lines, and the method of building has become popular with the public authority and private individual alike. As to the specialist contractor, it is his experience, and ability to do good work, that counts, not the system, if any, with which he may have originally been associated.—ED.

THE first opportunity which the German general public had of becoming acquainted with large structures of concrete and iron was at the Paris Exhibition of 1867, in the exhibits of Joseph Monier and François Coignet, although a boat of concrete with inserted iron rods was shown by Lambot in the first Paris Exhibition of 1855. After the Exhibition of 1867 it was Monier, whose name, as far as Germany was concerned, became identified with the new mode of construction, namely, that of the combination of two materials, cement and steel, of which one, the cement, could resist great compressive stresses, and the other, steel, great tensile stresses. The term "Monier system," was for many years alone expressive of this form of construction. Only when several systems had arisen were the more accurate general names of "Eisenbetonbau" or "Betoneisenbau" introduced into Germany.

The true nature of the new mode of construction was not recognised until consulting and practical engineers made a thorough study of it. Constructions of wood and iron, in which the relatively great resistance of the one material to compression and of the other to tension were utilised as far as possible, were already known in Germany—for instance, Howe's beams—but it was in reinforced concrete that it was first found possible to combine two different materials in the way most advantageous statically, the one material, iron, being embedded in the other, concrete.

In Germany, the invention was first commercially appreciated by the firm of Freytag and Heidschuch, of Neustadt-a-H., and the firm of Martenstein and Tosseau, Offenbach-a-M. In 1884 they acquired from Monier the patents for South Germany, and the right of pre-emption for the remainder of Germany. The civil engineer and contractor, G. Wayss, then entered the field. After he had bought the Monier patents for Germany from the above-named firms in 1885, he instituted, in conjunction with them, extensive experiments with structural members of reinforced concrete, paying attention not only to the load-carrying capacity, but also to the resistance to fire and to the behaviour of iron in concrete as regards corrosion. In this way he aroused the interest of the public authorities and building owners generally.

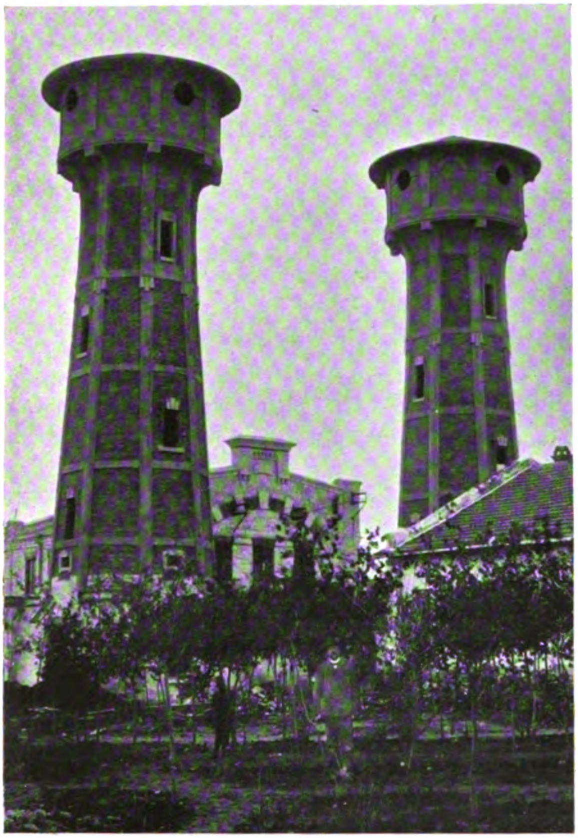


TYPICAL GERMAN REINFORCED CONCRETE FACTORY.

The results of these experiments were published in 1887 in a book entitled "The Monier System (Iron Skeleton with Concrete Filling) in its application to Building." (Berlin, A. Seydel and Co.) Of the greatest value to engineers were the theoretical arguments at about that time presented by M. Koenen, now director of the Concrete and Monier Construction Company, Berlin, for they served as a basis for the simple calculation of the strength of panels, floor vaults, cylindrical pipes and free-standing water reservoirs. These arguments were first published in the "Centralblatt der Bauverwaltung" in 1886.

Although this method of calculation, which was then in agreement with the loading experiments, has been superseded by later investigations, it nevertheless gave the new mode of construction a scientific foundation, and made the determination of dimensions in reinforced concrete work possible. When these rules did not suffice, loading tests were made, and are even now prescribed by the building authorities in difficult cases.

Koenen's theory took no account of the influence of the difference of elasticity between iron and concrete on the position of the neutral axis, but assumed this to lie at one-half of the height, as in the case of a homogeneous section. The values found by the formulæ are, therefore, compared with the modern methods of calculation, too favourable, the cross-section of the iron and concrete comes out smaller than by the later theory, since according to modern views the neutral axis only lies at the half-height of the section when the permissible stress in the concrete is 1/nth part of that in the iron, where n is the ratio of the elasticity of the concrete to that of the iron. For the usual value of $n = 15$, the axis lies at the half-height when the stress in the concrete is $\sigma_b = 80$ kg./cm.^{2} or 1,130 lb. per square inch. The concrete must then have, according to the usual specifications, a compressive strength of $5 \times 80 = 400$ kg./cm.^{2} or about 5,600 lb. per square inch.



Reinforced Concrete Frame Water Towers, as used in Germany.

The new theory was taken into account by Koenen in his work "Outlines of the Statical Calculation of Concrete and Reinforced Concrete Constructions."

Of great influence on the arrangement of the reinforcement is the consideration of the adhesion between iron and concrete, and the different systems of reinforced concrete construction differ mainly in the way in which the adhesive stresses are taken up by the concrete and the iron. Even a general comparison of the arrangement of the reinforcement in different countries shows that in Germany the method of increasing the adhesion between iron and concrete by the use of indented bars ("Wulsteisen") is not employed. Such bars are much used in America, but some authorities argue that they defeat the object aimed at, since, on account of the varying section of the iron and the consequently varying elongation and contraction, the concrete is sheared off from these expansions. Stress is therefore laid by prominent German investigators on giving each reinforcing rod a constant section. They consider that only in this way is it assured that the adhesive stresses at the surface of the metal are in accordance with the statical laws. But this point is, of course, still very much of a controversial character. Many English authorities of high standing, for instance, favour indented bars in a very marked manner.

The need of practical methods of calculation led the firm of Wayss and Freytag[*] to entrust their former chief engineer, E. Moersch, now professor at the Zürich Polytechnic, with the production of a comprehensive review of reinforced concrete construction as a whole. So the first edition of "Reinforced Concrete Construction, its Theory and Application," appeared in 1903 and the second in 1906.

In 1904, appeared the "Preliminary Rules for the Design, Execution and Testing of Reinforced Concrete Structures," drawn up by the Union of German Associations of Architects and Engineers and the German Concrete Association. These rules give an appropriate treatment of the considerations which enter into the practical construction of reinforced concrete, and led the Prussian Government to issue, on April 16th, 1904, the "Regulations for the Execution of Reinforced Concrete Work in Buildings," in accordance with which the examination by the building authority must take place. In consideration of the rapid progress of scientific investigation, the officials were instructed to report to the Ministry of Public Works their experience in the application of the rules during the first two years. We may, therefore, expect interesting and important communications with reference to reinforced concrete in a short time from the practical experience gained by the officials.

The "Rules for the Design, Execution and Testing of Rammed Concrete Structures," drawn up by the German Concrete Association (Berlin, 1905) and the "German Standards for the Uniform Specification and Testing of Portland Cement" should also be mentioned.

Since the careful requisitions of the German building authorities have been satisfied by the extensive precautions taken, reinforced concrete construction has made great progress in Germany, and at present there is hardly any kind of structure which has not been, more or less, successfully executed in reinforced concrete.

Reinforced concrete construction has not only given a great impetus to the cement industry and to the manufacture of round and square bar iron, but has brought into existence new categories of workmen. The price of gravel and sand has also increased. A few prices from the Berlin market may be of interest. Portland cement has risen since 1905 from 37 M. per cubic metre to 41 M., delivered, corresponding with 2.64 M. and 2.93 M. respectively per 100 kg., or 4.50 M. and 5.00 M. per normal cask of 170 kg. nett weight. Converted into English units this gives 27s. and 30s. respectively per ton of 20 cwt. Pit gravel costs about 5.50 M. delivered, dredged ballast 6.00 M. Reinforcing iron costs 15 M. per 100 kg. The special workmen engaged in reinforced concrete work in Greater Berlin, that is, the city of Berlin and its 42 suburbs, receive 6.00 Mk. per working day of eight hours.†

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[*] This firm has kindly put the illustrations to this article at the author's disposal.

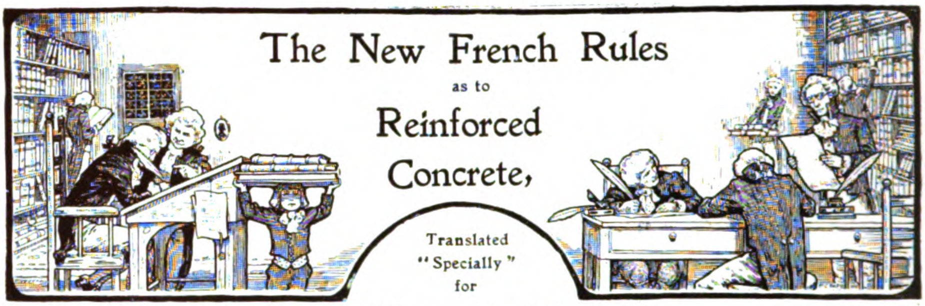
[†] Mk. = Marks approximating 1s.; 20 marks = £1.

The efforts of modern constructors in Germany are directed mainly towards making the building as permanent as possible, since in Germany, where until the introduction of the new Civil Code on January 1st, 1900, no system of ground rents existed, and the English system of leasing sites for building purposes is unknown; each proprietor aims at making his house as durable as possible, so that he and his successors or assigns may enjoy its use for the longest possible time.

It is in fact with the object of advocating sound construction and the substantiality of buildings generally that the "Building Association" was founded in Berlin under the leadership of Herr Jaffé, the well-known Prussian Government Surveyor. This Society has specially set itself the task of promoting reinforced concrete construction, steel and concrete buildings, etc.

Yet the development of reinforced concrete construction is far from having reached its limit. Only long experience can show which types will survive, since not only the load-carrying power, but also many other qualities, which it is impossible to express in detail, are of importance in judging the value of a method of building construction.

TYPICAL GERMAN REINFORCED CONCRETE BRIDGE.
(Bridge over the Isar, near Munich.)



The New French Rules as to Reinforced Concrete,

Translated "Specially" for

"Concrete and Constructional Engineering."

(Copyright, 1906, by Walter Roden in the United States of America.)

We present herewith a specially prepared translation of the important Instructions, i.e., Rules on Reinforced Concrete, just about to be issued by the French Ministry of Public Works, together with an Explanatory Circular of the highest possible interest.

Without in any way, at this stage, commenting upon either the Rules or the Circular, we would emphasise what is indicated below, that this publication is based upon the work of a special commission of some five years' standing, and upon the elaborate investigations conducted at the instance of that Commission.

If the Rules and the Circular do not in every way suit the conditions of design and workmanship beyond the borders of France, and thus cannot serve as a universal model, they nevertheless can be everywhere used as a skeleton upon which to base enactments.

Any slight revision which may be found necessary upon actual official issue of the Rules will be announced in a subsequent issue.

As to our translation, it has been prepared by a French civil engineer of high standing, and revised by one of our most valued regular contributors, and if it lacks perfection it will not be for the want of care. To parties desirous of reprinting this translation, we should perhaps sound a note of warning that we are protected by copyright (including United States copyright) but shall be happy to meet, as far as possible, any requests of would-be users, who may apply to us in writing for permission.—ED.

THE popularity of reinforced concrete for structural work in France caused the French Government, as far back as 1901, to recognise the necessity of issuing data for the guidance of designers generally and their own technical staff in particular.

Thus the "Commission du Ciment Armé" came to be appointed in 1901 by the Ministre des Travaux Publics, with instructions to investigate the properties of the material and to elaborate administrative rules to be applied in official contracts.*

The first meetings of this Commission were held in March, 1901, in order to determine the programme of the research work to be carried out. This research work was ordered to comprise enquiries as to the mechanical behaviour of mortar and concrete, with or without reinforcement, more particularly as to the laws of compressive, tensile, shearing, slipping and adhesive stresses, the variations of volume resulting from the hardening process and from climatic changes; further, the influence of the proportions and of the qualities of ingredients, the relative efficiency of various arrangements for reinforcement, the degree of water-tightness, fire resistance and wear, the effect of shocks and any reciprocal assistance afforded to each other by neighbouring members in structures. Further, certain tests "to destruction" were ordered upon various structures in reinforced concrete that had been erected in 1900 for the Paris International Exhibition.

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* The Commission comprised MM. Lorieux, Inspecteur-Général (chairman); Rèsal Rabut, Bechmann, Considère, Harel de la Noë, Mesnager, Ingénieurs-en-Chef, Professeurs à l'Ecole des Ponts et Chaussées; Boitel, Royal Engineer Officer; Hartman, Artillery Officer; Gautier and Hermant, Architects; Candlot, Coignet and Hennebique, specialist civil engineers or contractors.

Five years were not too much for such a comprehensive programme of experimental research work and for deducing therefrom accurate data.

Numerous meetings were held to formulate the results obtained, and the conclusions of the "Commission du Ciment Armé" were finally submitted to the Ministry in March, 1906, and referred by them for approval by the Conseil Général des Ponts et Chaussées, who selected three of their members* to examine the proposed rules. This committee thoroughly inquired into every point; calling upon the leading members of the "Commission du Ciment Armé" to argue their cases personally, and hearing with deference the arguments of the minority of the Commission,† who had so strongly advocated the separation of the Instructions into two parts—Rules, and an explanatory Circular.

The actual reason why the Rules are officially termed "Instructions" is, we believe, due to their being considered provisional.

We present a full translation of the "Instructions" (Rules) and also of the explanatory "Circular," which affords such interesting reading. As to the "Instructions" however, we may usefully indicate certain features in summary as follows:—

THE LIMIT OF THE SAFE STRESSES PERMISSIBLE IN DESIGNING STRUCTURES IN REINFORCED CONCRETE.

Compression.—Two-sevenths of the crushing strength of the same concrete tested without reinforcement in the form of a cube after 90 days' hardening. This rate of two-sevenths may be increased to three-fifths if the longitudinal and transverse reinforcement comply with certain conditions.

Shearing, Slipping and Adhesion. One-thirty-fifth of the crushing strength ascertained as above for plain concrete.

Tensile and Compressive Reinforcement.—One-half of the apparent limit of elasticity to be specified under ordinary conditions and five-twelfths only if shocks are likely to occur.

All these safe stresses are to be decreased, but by 25 per cent. at most, when any weakening cause may be foreseen.

Only scientific formulæ are to be used. Empirical formulæ will not be allowed.

The tensile strength of concrete is to be considered in order to determine general deformation; but for computing local stresses it will be considered as *nil*.

The "Circular" explains that the ratio m of the moduli of elasticity of steel and of concrete was found experimentally by Messrs. Rabut and Mesnager to be equal to 10, but that this figure should not be applied indiscriminately to all cases; and that the value to be inserted in the formulæ derived from the elastic theory may vary from 8 to 15, according to the diameter of the longitudinal reinforcement and the spacing of the transverse reinforcement in relation to the least dimension of the member under consideration.

For members subjected to direct compression another coefficient m' is to be considered besides the coefficient m amplifying the volume of the longitudinal reinforcement, and permitting this latter to be summed up with the volume of concrete in order to compute the total sectional area of a hypothetical homogeneous section equalling, from a mechanical aspect, the heterogeneous sectional areas. This coefficient *m'* allows the amplification of the total sectional area (hypothetically homogeneous), according to the ratio of the volume of transverse reinforcement to the volume of concrete and the more or less close spacing of the bars.

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* Maurice Lévy, Inspecteur-Général, 1ère Classe, Membre de l'Institut; de Préaudeau, Vetillard, Inspecteurs-Généraux de 2ème Classe.

† Which comprised MM. Rabut and Mesnager,

The tenour of these rules is to induce designers to use, as far as possible, large sections of ribs, small diameters of reinforcing bars, and closely-spaced stirrups.

Copyright Translation, subject to revision.

"Instructions" (Rules) for the Design of Structures in Reinforced Concrete.

I. DATA TO BE ALLOWED IN DESIGNING.

A.—Loads.

1. Bridges in reinforced concrete are to be designed in accordance with the same vertical loads and the same wind pressures as those required by the Ministerial regulations of August 29th, 1891, dealing with steel girder bridges of similar types.

2. Roofs in reinforced concrete shall be treated from the point of view of loads as far as possible in accordance with the French Ministerial regulations of February, 17th, 1903, dealing with metallic halls for railway lines.

3. Floors and other structural features of buildings, retaining walls, tanks, water mains under pressure and any construction whatsoever affecting the public safety, are to be designed with regard to the maximum loads which such structures may have to carry.

B.—Safe Working Stresses.

4. The limit of compressive stress of reinforced concrete to be allowed in calculations shall not exceed $\frac{2}{7}$ of the crushing strength of plain concrete of the same proportions and at the age of 90 days. The value of the crushing strength, determined by tests upon 8 in. cubes at least, to be specified in every contract.

5. When hooping, transverse, or oblique reinforcement is employed, if arranged suitably to resist the buckling effect due to longitudinal pressure, the safe limit referred to in Article 4 may be increased to some extent in proportion to the volume of reinforcing bars, and to their more or less suitable arrangement; but, whatever may be the percentage of the reinforcement employed, the limit of compressive strength shall not exceed $\frac{3}{6}$ of the crushing strength of plain concrete as stated in Article 4.

6. The safe limit for shearing and slipping strains in the concrete in respect of its own fibres, as well as the safe limit of its adhesion to the metal used as reinforcement, may be taken as equal to $\frac{1}{10}$ of the strength specified in Article 4 for the safe limit of compressive stresses.

7. The safe limit of tensile, as well of compressive stresses allowed for the reinforcement shall not exceed one-half the value of the elastic limit of the metal employed, and as specified in the contract. However, for members, and especially for slabs subject to alternating shocks or stresses, this limit is to be reduced to $\frac{5}{12}$ instead of one-half the elastic limit.

8. For members subject to stresses varying within wide limits, the safe working stresses specified above are to be reduced in accordance with the importance of such variations, but this decrease need not exceed 25 per cent.

The safe limits of the working stresses are to be reduced also for members subject to weakening causes not considered in the calculations, particularly to dynamical action, and especially for members directly supporting railway lines.

II.—CALCULATIONS.

9. The designer of structures in reinforced concrete has to take into account not only the most unfavourable external forces, including the weight of wind and snow, but also the strains resulting from changes of temperature and those due to the expansion and contraction of the concrete when the structure cannot be considered, with some certitude, as being freely dilatable, theoretically or practically.

10. Calculations are to be based upon scientific methods derived from experimental researches, and not upon empirical formulæ; the calculations may be deduced either from the principles of the elastic theory or from principles presenting at least an equivalent guarantee of exactitude.

11. The tensile strength of the concrete shall be taken into account when calculating deformation, but when computing the local stresses in any section, the tensile strength of the material is to be considered as *nil.*

12. When a member subjected to direct compression is free over a length exceeding 18 diameters (or the least side), it is necessary to inquire whether it is liable to flexure.

III.—CONSTRUCTION OF WORKS.

13. The moulds and centerings, as well as the disposition of the reinforcement, must afford sufficient rigidity for withstanding, without noticeable deflection, the loads and shocks occurring during construction, including those caused by the removal of moulds and centerings.

14. Except in special cases where concrete is poured, the cement used shall be slow-setting, and the concrete carefully tamped in successive layers, whose depth shall be suited to the dimensions of the aggregate and to the spacing of the reinforcement; this depth shall not exceed 2 in. after tamping, except in cases where stones are employed as aggregate.

15. The reinforcing bars are to be so spaced one from the other and from the sides of the moulds, that perfect ramming of the concrete may be facilitated, and that the concrete may be forced into contact with the reinforcement. The thickness of concrete intended to protect the reinforcement against changes of temperature must be at least ¾ in., even in cases where cement mortar is used in place of concrete.

16. When special sections are employed for reinforcement instead of round bars, arrangements must be made to provide for the perfect encasing of the bars around their entire perimeter and particularly at all re-interring angles.

17. When the construction of a work has been stopped (an occurrence that shall be avoided as far as possible), the concrete is to be cleaned, scraped and watered for a sufficient time to moisten it thoroughly, before fresh concrete is deposited.

18. In frosty weather the work must be discontinued if efficacious means for preventing the prejudicial effects of frost are not available. In resuming the work, any part of the concrete which may have been injured is to be cut out. In other respects, work is to be conducted in accordance with Article 17.

19. During 15 days, at least, the concrete must be kept sufficiently moist to insure its setting under favourable conditions.

The quality and proportions of the ingredients of the concrete are to be specified in the contract. The amount of water used in gauging shall be supervised accurately, and must be sufficient for insuring the fluidity necessary for the perfect embedding of the reinforcement and the complete filling of all voids between the various ingredients of the mixture.

20. The moulds and centerings are to be removed without any shock; the stresses developed in removing them must be merely static and the set of the concrete ought to be sufficient for withstanding such stresses.

IV.—TESTS OF WORKS.

21. Structures in reinforced concrete affecting the public security must be tested before use. The conditions of testing, as well as the limit of deflection allowed, are to be stated in the general specifications.

The age of the works tested shall be specified also. It must attain at least 90 days for structures of primary importance, 45 days for ordinary constructions, and 30 days for floors.

22. The engineers* shall have, in testing, the opportunity not only of observing the deformations and of verifying other specified conditions, but also, as far as possible, of making scientific investigations.

23. Bridges in reinforced concrete are to be tested in accordance with the methods prescribed by the Ministerial regulations of August 29th, 1891, above referred to.

Any variations from those regulations that would appear suitable in any particular cases are to be justified and specified in the contract.

24. Roofs shall be tested as prescribed in the Ministerial regulations of February 17th, 1903, above referred to, subject to approved variations.

25. Floors shall be subjected to tests comprising the application of the calculated permanent and moving loads acting over the whole area of the building, or at least upon entire floor panels.

The loads are to be left in position for at least 24 hours, and increase of deflection must cease after 15 hours.

Circular explaining the Instructions for the Design of Structures in Reinforced Concrete.

Copyright Translation, subject to revision.

In consideration of the extensive development evidenced in reinforced concrete construction as applied to public works, it is necessary to call the attention of the engineers† to the general conditions under which buildings erected in this new material present the same features of stability and offer the same guarantees of safety to the public as those carried out in materials that have been in use for a long time.

Such is the scope of these Instructions. While complying with the actual state of our knowledge on the matter, they may probably be modified when the experience derived from works executed or from laboratory experiments and from the longer use of reinforced concrete shall have furnished more accurate data than those available at the present moment.

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* **Ingénieurs des Ponts et Chaussées.**

† In this and all subsequent cases where the words "the engineers" are used, they refer to the Ingénieurs des Ponts et Chaussées.—Ed.

The object of the following explanations is to define more accurately, so far as appears necessary, the meaning and scope of the Instructions.

I. DATA TO BE ALLOWED FOR DESIGNING.

A. Loads.

Articles 1, 2 and 3. The two first articles require no comment. The third, prescribing that the structures dealt with are to be designed for the most unfavourable loads that they may have to bear when in use, appears unnecessary, as every work must be carried out and thus designed in view of the purpose for which it is destined.

That is true for metallic structures or any other class of building construction employed before the introduction of reinforced concrete. Such buildings are designed in view of supporting with a suitable factor of safety the greatest actual loads to be foreseen, that is to say, so that under the influence of these loads the elastic stress shall not exceed a determined ratio of the loads capable of producing rupture.

Some specialists have suggested another mode of procedure for the design of structures in reinforced concrete. Instead of deducing the elastic stresses from the actual loads, their method involves inquiry into the proportion by which these loads would have to be fictitiously increased to cause rupture, this ratio of amplification determining the factor of safety.

This method of proceeding, while sometimes interesting, evidently does not afford a sufficient guarantee of safety, for the sinking of a building is never caused by a proportional amplification of the loads it has to support. The collapse of a structure is rather the consequence either of an accidental occurrence or of an internal injury whose development becomes destructive.

Under such conditions it appears proper to design structures in reinforced concrete, as in the case of other constructions, for the most unfavourable loads they may actually have to support and with such a factor of safety as to give an adequate assurance of stability.

Although the first method is obligatory, the engineers may supplement, if they think proper, with calculations based on the amplification of real loads in order to ascertain the hypothetical loads capable of causing rupture, and they may state the conclusions they deduce from these calculations.

B. Safe Working Stresses.

4. The value of the safe working stress in compression of the concrete without reinforcement, limited to $\frac{2}{7}$ of its crushing strength after 90 days' hardening, is far higher than the value generally allowed abroad. The figures found in foreign rules correspond rather to an allowance $\frac{1}{4}$ of the crushing strength of plain concrete of equivalent proportions after 28 days' setting.

Making comparison between the two rules for three mixtures of reinforced concrete examined by the Commission du Ciment Armé, the following results are found:—

The mixtures tested by the Commission were composed of 400 litres sand and 800 litres gravel and respectively: 300 kilogrammes; 350 kilogrammes; 400 kilogrammes Portland cement.

The ultimate compressive strengths found for these concretes expressed in kilogrammes per square centimetre were as follows:—

After 28 days.

107 kilogrammes, 120 kilogrammes, 133 kilogrammes—(*a*)

After 90 days.

160 kilogrammes, 180 kilogrammes, 200 kilogrammes—(*b*)

Assuming the limit of the safe stress be $\frac{1}{4}$ of the ultimate strength (*a*), we have respectively:

27 kilogrammes, 30 kilogrammes and 33 kilogrammes per cm^2.

Admitting on the contrary $\frac{2}{7}$ of the strength (*b*) according to Article 4 of Instructions, we have:

45·7 kilogrammes, 51·4 kilogrammes, and 57·1 kilogrammes per cm^2.

or almost double the previous values,

Therefore, from this standpoint, Article 4 appears far bolder than the foreign rules. But these latter being relatively old, may soon be revised and probably modified so as to come into line with the provisions of Article 4.

As French designers comply more willingly than foreign engineers with administrative regulations even for private works, the boldness of Article 4 will be favourable to the development of the reinforced concrete industry. In any event, designers remain liable for the data they apply.

Otherwise the engineers are not obliged to adopt the ultimate limit of the allowance; they can prescribe lower limits and should remember that whatever stress limits may be adopted, the stability of structures in reinforced concrete depends very largely upon the perfect quality of the ingredients, their mathematical admixture, and their accurate application. Supervision is to be still more rigorous for such structures than for those in ordinary materials

5. The intelligent use of the metal, not only for longitudinal but also for the transverse and oblique reinforcements, is to be encouraged, in order that it may be able to assit the concrete to withstand the buckling action due to longitudinal pressures. Under these conditions crushing strength increases very largely, and when the transverse reinforcement constitutes hooping of sufficiently close spacing this increase is considerable, as experiments have shown. Therefore, a higher allowance for the safe working stress seems logical, and this increase is to be determined by the volume and the suitable arrangement of the transverse reinforcement. It would be difficult to ascertain the laws governing this increased resistance. Some tests made in laboratories, or carried out in works, in prisms of concrete without reinforcements and with suitable transverse reinforcement, suggest the rate of increase of the crushing strength of the latter, and, therefore, the corresponding amplification of the safe working stress to be allowed. Nevertheless, according to the experiments made by the Commission du Ciment Armé, it must be admitted, *faute de mieux*, that the transverse reinforcement and the hooping multiply the crushing strength of a prism of concrete by a co-efficient:

$$1 + m'\frac{V'}{V}$$

V' being the volume of the transverse or oblique reinforcement and V the volume of concrete corresponding to the same length of prism: m' is a co-efficient varying with the degree of efficiency of the bond provided between the longitudinal bars. This bond being realised by transverse ties constituting rectangles, if projected on a cross section of the prism, the co-efficient m' may vary from 8 to 15, the *minimum* relating to a spacing of the transverse reinforcements equal to the least dimension of the specimen considered, and the *maximum* corresponding to a spacing equal at least to the third part of that dimension.

When the transverse reinforcement is compounded of more or less close windings, m' may vary from 15 to 32, the *minimum* being applied to windings spaced $\frac{2}{5}$ of the least transverse dimension of the specimen considered, and the *maximum*, if this spacing reaches $\frac{1}{5}$ of the above dimension for a longitudinal pressure of 50 kilogrammes per square centimetre, or $\frac{1}{8}$ of the above dimension for a longitudinal pressure of 100 kilogrammes per square centimetre.

But in any case, whatever may be the percentage of such reinforcement and the value of the coefficient $1 + m'\frac{V'}{V}$, the former indications have to comply with the essential condition specified in Article 5, viz: that the safe working stress to be allowed must not exceed $\frac{3}{5}$ of the strength of plain concrete, such as are described in Article 4. The effect of this requirement is, in every case, to keep the working stress within such limits as not to exceed one-half of the pressure causing the first surface cracks in the reinforced concrete; which, according to the experiments of the Commission du Ciment Armé, may exceed by from 25 to 60 per cent. the pressure causing the crushing of plain concrete.

II.—CALCULATIONS.

9. This article requires no explanation or comment.

10. The scope of this article is to obviate empirical methods of calculations. The principles of the elastic theory allow safer solutions in the case of reinforced concrete as for ordinary structures. It may be admitted within the limits of experimental researches known up to date, that Navier's theory of the plane deformation of the cross section, can be applied here also.

This latter, coupled with the principle of proportionality between deformation and stress, is sufficient in the case of members subjected to pressure, if every heterogeneous section is replaced by a hypothetical section having the same mass as the real heterogeneous section, and if a density 1 is imputed to the concrete features and a certain density* m to the longitudinal reinforcements. Theoretically, the density m would be the ratio:—

$$m = \frac{Es}{Ec} \quad \dots\dots\dots\dots\dots\dots\dots (1),$$

of the modulus of elasticity Es of the reinforcement to the modulus of elasticity of concrete Ec. The value of this ratio is about 10 within the limits of loads assumed in Article 4. It increases with the loads of concrete, and may double or triple when rupture occurs by crushing; it will decrease on the contrary in case of rupture caused by failure of the reinforcement.

This fact would suffice to show the incertitude of calculations based on a fictitious increase of loads up to rupture, as stated in Article 3.

In all cases the experiments in view of the determination of Ec were made with plain concrete. To what extent the ratio m deduced from those experiments may be applied to reinforced concrete? That depends, probably, on the degree of facility with which the members may be rammed in all their parts for a complete embedding of the reinforcement.

Therefore, it is preferable to consider the co-efficient m as resulting from tests and not necessarily as representing, in a member with complex longitudinal and transverse reinforcement, the ratio of the elastic moduli of the metal and of the concrete tested separately.

It will be assumed that this co-efficient may vary from 8 to 15. The minimum is to apply to diameters of longitudinal bars equal to $\frac{1}{10}$ the least dimension of the member, the ties or transverse reinforcement being spaced apart, this latter dimension, and having their ends sufficiently near the surface of the concrete. The maximum is to be applied in the case of diameters of bars equal to $\frac{1}{20}$ of the least dimension of the member, and their spacing reduced to $\frac{1}{3}$ of this dimension.

Most authors admit a constant value for m and often take $m = 15$. By so doing, they may ascribe in many cases too much strength to the metal and too little to the concrete in relation to the stresses really occurring. In consequence of this assumption, the working stress of concrete may be, in fact, higher, and the factor of safety lower than is presumed.

Letting m vary from 15 as maximum to 8 as minimum according to the disposition of the reinforcement, longitudinal and transverse as well, the truth is approached more nearly, and compensation is found for the rather high working stress allowed in Article 4.

Once the coefficient m has been decided, it is easy to apply formulæ under the classical form dealing with homogeneous bodies.

(*a*) *Simple compression.*—The hypothetical homogeneous sectional area Ω is given by the relation:—

$$\Omega = \Omega_c + m\Omega_s \quad \dots\dots\dots\dots\dots\dots (2),$$

Ω c, being the sectional area of concrete and Ω s the total area of the cross sections of the longitudinal reinforcement. The latter being very little in proportion to the first, it should be noted that we may consider the total area $\Omega c + \Omega s$ instead of Ωc of the member.

Let N be the total pressure acting normally to the section, Rc the pressure per unit area borne by the concrete, and Rs the compression supported by the reinforcement, we get:—

$$R_c = \frac{N}{\Omega}, \quad R_s = m\frac{N}{\Omega} \quad \dots\dots\dots (3),$$

Rc being assigned, Ω is deduced and then, by means of formula (2), according to the actual shape of the member, the total area Ω s of the reinforcement or the percentage:—

$$\frac{\Omega_s}{\Omega_c}.$$

(*b*) *Compression with flexure.*—If the total compression N is not uniformly distributed, besides the area Ω of the hypothetical section, resort must be had to the centre of gravity of the section and to its moment of inertia about the perpendicular to the direction of flexure drawn through the centre of gravity, according to the following equations :—

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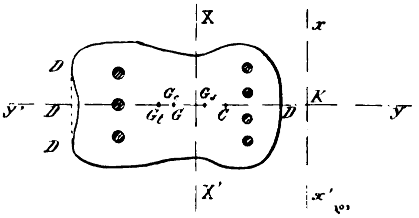
* The transverse reinforcement has nothing to do here. Its essential effect is already taken in consideration in permitting increase of (Article 5) the safe limit of the compression of concrete. In fact the leading efficiency of the transverse reinforcement is to increase the crushing strength of concrete by withstanding the transverse buckling.

$$\Omega y = \Omega_c y_c + m\Omega_s y_s \quad \ldots\ldots\ldots\ldots (4),$$

$$I = I_c + mI_s \quad \ldots\ldots\ldots\ldots\ldots\ldots (5).$$

Fig. 1 is a diagram of the section considered, assumed to be symmetrical about the axis y′y. The centre of gravity of the hypothetical section Ω to be ascertained is G; that of the reinforcement Gs is known; that of concrete Gc is also known. These points are determined by their respective ordinates :—

Fig 1.



$$y = GK, \quad y_c = G_c K, \quad y_s = G_s K,$$

starting from the axis x′x, arbitrarily chosen, and expressed conventionally with the + sign when on one side, and with — sign when on the opposite side. Equation (2) gives Ω; then equation (4) gives the ordinate of the centre of gravity G of Ω; next, the axis xGx′ being known, the moments of inertia Ic and Is of the geometrical areas of concrete, and longitudinal reinforcement can be computed about that axis, and finally, equation (5) gives the moment of inertia I of the hypothetical section Ω, about the same axis.

It was said above that the total section $\Omega t = \Omega c + \Omega s$ of the member is sometimes taken instead of the section Ωc of concrete. If not so taken, equations (2), (4) and (5) may be written more handily in practice by inserting the total area instead of Ωc, the area of Concrete $\Omega t = \Omega c + \Omega s$. Then, inserting instead of the centre of gravity G_c of concrete (that G_t), of the total section, and instead ot the moment of inertia, I_c of the sectional area of concrete about the axis x′x the moment of inertia I_t of the total section about an axis parallel to x′x passing through the centre of gravity C_t.

The formulæ then become :—

$$\Omega = \Omega_t + (m-1)\,\Omega_s, \ldots\ldots\ldots\ldots\ldots\ldots (2).$$

$$\Omega y = \Omega_t y_t + (m-1)\,\Omega_s y_s, \ldots\ldots\ldots\ldots (3 .$$

$$I = I_t + \Omega_t (y - y_t)^2 + (m-1)\,I_s \ldots\ldots (4).$$

Then, N being the total pressure and M the bending moment, or the sum of the moments of external forces acting on the section considered about the centre of gravity G of the hypothetical section, the unit pressure n_c acting on the concrete at any distance v from the axis x′x will be :—

$$n_c = \frac{N}{\Omega} + \frac{M}{I}\,v, \ldots\ldots\ldots\ldots (5).$$

and if at the point considered there is a bar of reinforcement, its corresponding stress would be :—

$$n_s = m n_c. \quad \ldots\ldots\ldots\ldots\ldots (6).$$

In these formulæ, the distance v is to be considered as positive on the side where the bending moment causes compression, and as negative on the opposite side. If the bending moment about the axis x′x is considered positive from left to right for an observer placed on x′x, the head in x′, the feet in x, then the distances v are to be considered positive for the points of the section located at the right of x′x and negatively for those laying at left.

Let us call v_c the distance from x′x of the extreme fibres at the right hand, v_{1c} the *absolute value* of the same distance for the extreme fibres at the left hand, the maximum compression of concrete R_c per unit of area will be :—

$$R_c = \frac{N}{\Omega} + \frac{M}{I}\,v_c \ldots\ldots\ldots\ldots (7).$$

The minimum compression R_{1c} will be :—

$$R_{1c} = \frac{N}{\Omega} - \frac{M}{I}\,v_{1c} \ldots\ldots\ldots\ldots (7').$$

Replacing the suffix *c* by *s* for the reinforcements, the maximum values of compression for the reinforcements will be :—

$$R_s = m\left(\frac{N}{\Omega} + \frac{M}{I}\,v_s\right) \ldots\ldots\ldots (8),$$

$$R_{1s} = m\left(\frac{N}{\Omega} - \frac{M}{I}\,v_{1s}\right) \ldots\ldots\ldots (8').$$

These formulæ assume essentially that there is compression at all points, or, in other words, that the value R_{1c} and therefore the value R_{1s} are positive. If R_{1s} were negative they could not be applied, because the laws of extension of concrete differ essentially from those governing its compression. The proper process will be indicated hereafter.

If we know the total pressure N in amount and direction, that is, if we know the position of its point of application (centre of pressure) determined by its co-ordinate v_o about the axis x′x, it can be deduced by definition that :—

$$M = N v_o \ldots\ldots\ldots (9)$$

Then writing :

$$I = \Omega r^2 \ldots\ldots\ldots (10)$$

r being the radius of gyration of the hypothetical section about the axis x′x, we should get :—

$$n_s = \frac{N}{\Omega}\left(1 + \frac{v_0 v}{r^2}\right) \ldots\ldots\ldots (11).$$

The neutral axis would be obtained, by expressing the value $n_c - o$, or :—

$$1 + \frac{v_0 v'}{r^2} = 0 \quad \ldots\ldots\ldots\ldots (12),$$

if we call v′ the value of v, determining the position of this axis.

With these new notations, equation (7) becomes :

$$R_{1c} = \frac{N}{\Omega}\left(1 - \frac{v_0 v_{1c}}{r^2}\right) \ldots\ldots\ldots (13).$$

Comparison of the two last formulæ shows, as it ought, that there is compression at all points only when the neutral axis falls outside the section, or :

$$-v' > v_{1c}.$$

The above consideration supposes that the values of N and M are known for every section. Such will be the case for a column bearing a central load (that is applied in the centre of gravity of the hypothetical section, where M o), or eccentric, where ($M = N v_o$). It will similarly be the case in a dam for which the line of pressures gives in fact N and v_o for every section.

When these values are not given directly by static methods, as in the arch of a bridge, it is necessary to proceed as in the far most general case of members at once compressed and extended, a case which really justifies the use of reinforcement, and we enter naturally upon the treatment of the case dealt with by Articles 11 and 12 of the Instructions.

It was stated in that Article, that in calculations dealing with deformation, the tensile strength of concrete is to be taken into account. These calculations are necessary when the deformation is to be determined, particularly to estimate the deflection taken by the work. But in every case these formulæ of deformation are to be applied for computing in all sections the pressure N of the *average fibre* (geometrical locus of the centres of gravity G of the hypothetical sections Ω), the bending moment M, and the shearing stress T, when they cannot be determined by static methods.

By definition, N and T are the normal and tangential components of the external forces, including the reaction of the support acting on a determined side of the section, and M is the sum of the moments of the same external forces about the point G.

In the case of a column with one end free, or of a beam simply supported at the ends, the forces N and T and the couple M can be *accurately* computed. Hence no formula of deformation, and therefore no assumption, are required in order to determine them. Article 11 does not deal with this part of the subject.

But in the case of built in or continuous beams, extending over several supports, or of arches subject to tensile stresses, the general rule for arches of reinforced concrete (Article 11) is to be applied, and consequently wants to be interpreted.

The engineers may accept the usual interpretation, although inaccurate, while assuming for concrete subjected to tension the same coefficient of elasticity as when submitted to compression.

This assumption once made, the foregoing formulæ may be applied in their entirety, under the essential restriction that compressive stresses only are dealt with.

Now it is easy to see that these formulæ, owing to the intervention of the features of the hypothetical section Ω, permit us to substitute for the problem of resistance of a reinforced concrete member—that is of a heterogeneous member—by a problem of resistance of a hypothetically homogeneous member. Then all the general and classical results deduced in respect of the latter case may be applied to the former, and in consequence, in order to compute the values of N, M and T for an arch, and the values of M and T in the case of a beam transversely loaded—where N = o, as the reactions over the supports—it will suffice in every case to insert the well-known values referring to homogeneous members.

So, if we have a reinforced concrete beam with a span *l*, built in at both ends and supporting a uniformly distributed load of *p kilogrammes* per lineal unit, it will be admitted as for an homogeneous beam, that the maximum bending moment developed at the ends will be $\frac{pl^2}{12}$, and that the bending moment at the centre will be of opposite sign and equal in absolute value to $\frac{pl^2}{24}$.

For a beam with the ends partially built in the intermediate value $\frac{pl^2}{10}$ may be adopted between $\frac{pl_2}{24}$ and $\frac{pl^2}{8}$ for a beam free on both supports.

In the same way, for a continuous beam extending over several supports generally equidistant the values given by treatises on the strength of materials for bending moments, shearing forces and reactions of the supports, for homogeneous members, may be applied, or in special cases, may be determined directly in the same manner as for homogeneous members.

In the same way, for the design of arches, the tables of M. Bresse relative to homogeneous arches may be used to compute the thrust of a two-hinged arch, and the tables lately published by M. Pigeaud, in the *Annales des Ponts et Chaussées*, on the case of an arch built in, and intermediate values may be adopted between those given by these tables if the building in is thought to be only partial.

In special cases the thrust will be directly computed by the classical formula for homogeneous members.

The thrust and the vertical reaction once known, all the necessary data will be at hand to determine M, N and T graphically or mathematically for any desired section.

More Accurate Interpretation.—The tensile strength of concrete may be taken in account more accurately if we admit as resulting from various experiments the following principle: the modulus of elasticity of reinforced concrete, subjected to tension, may be considered nearly constant until the ultimate tensile strength of the same concrete without reinforcements is reached; the material becomes to some extent plastic, that is, it is lengthened in consequence of its connection with the reinforcement, but without any alteration of its ultimate strength in tension. There is no difficulty in setting up a theory of the resistance of materials based on this hypothesis, coupled with the assumption of Navier concerning the plane deformation of cross-sections. But the calculations become far more complicated. However, the engineers may recommend this method if they find it more suitable.

Whatever may be the method adopted for the determination of the values of the bending moment M, of the shearing force T, and of the pressure of the average fibre (which is zero in the straight beams transversely loaded); the local stress is to be deduced, at any rate for the most heavily loaded sections. Article 11 prescribes that the tensile strength of concrete is not to be considered for that object. This requirement is not at all contradictory with the prescription that it should be taken into account for the calculation of deformation. In fact, the cracks of the concrete are more or less of importance near the reinforcement in tension, but the alteration of the general deformation of the structure caused by these hair surface cracks is scarcely appreciable, even if, at a point, a more apparent crack is produced. But at any such point the local stress would obviously be extensively increased. It is, therefore, proper to admit this unfavourable hypothesis in the calculation of local stresses, while it would be improper to admit them in the investigating of general deformation, and consequently for the computation of the values of M, T, N depending upon them.

Application to a Slab in Combination with a Rectangular Beam.

We will now apply the method stated above to a slab (*Fig.* 2), assimilated to a T beam, the height of which is *h*, the breadth of the flanges is *b*, the breadth of the rib is *b'*, the depth of slab is ε, and the total sectional area of the reinforcement in compression is ω, its average distance from the compression face is *d*; the sectional area of the reinforcement in tension is ω', its distance to the tension face is *d'*. If the former reinforcement does not exist, ω = o.

Let y be the unknown distance of the neutral axis $x'x$ from the compressed face B. In *Fig.* 3 the section of the slab is projected about the straight line AB. The ordinates of the straight line XB′ represent the pressures of concrete, and if m is neglected the ordinate bb′ represents the pressure of the compressive reinforcement, and aa' represents the stress of the tensile reinforcement. Let K be the angular co-efficient or trigonometrical tangent of the angle B′xB.

Fig. 2

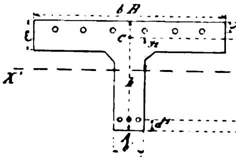
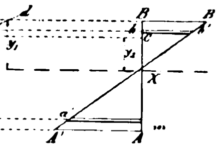


Fig. 3.



(*a*) *Simple Flexure.*—In case of simple flexure N=o. Assuming that the elastic forces are limited to the couple of flexure M,—that is, their sum=O—and the sum of their moments about any point—for instance, about the point B—is equal to M; then the distance XB=y_1 of the neutral axis from the compressed face is given by the quadratic equation :—

$$O = \frac{b'y_1^2}{2} + (b-b')\epsilon\left(y_1 - \frac{\epsilon}{2}\right) + m\omega(y_1-d)d$$
$$-m\omega'(h-d'-y_1) \text{ .... } (16),$$

then to determine the angular coefficient K :—

$$\frac{M}{K} = \frac{b'y_1^3}{6} + (b-b')\epsilon^2\left(\frac{y_1}{2} - \frac{\epsilon}{3}\right) + m\omega(y_1-d)$$
$$-m\omega'(h-d'-y_1)(h-d') \text{ .... } (17),$$

where the second term and M also are known.

These formulæ pre-suppose that the neutral axis is included in the rib; if included in the slab, it suffices to make b′=b in the previous formula, and we get :—

$$O = \frac{by_1^2}{2} + m\omega(y_1-d) - m\omega'(h-d'-y_1) \text{...... } (18),$$

$$\frac{M}{K} = \frac{by_1^3}{6} + m\omega(y_1-d)d - m\omega'(h-d'-y_1)(h-d')$$
$$\text{...... } (19).$$

To ascertain where the neutral axis falls, and, therefore, to know which of the two formulæ, (16) or (18), is to be employed, it suffices to substitute in the second term of (16) ϵ for y_1. Whence we have :—

$$\frac{b\epsilon^2}{2} + m\omega(\epsilon-d) - m\omega'(h-d'-\epsilon).$$

If the numerical value of this expression is positive, the neutral axis falls within the slab and is to be computed by means of formula (18). If this value is negative, the proceeding is inverted.

Formula (18) and (19) may be applied also to a rectangular section, the base of which is b and the height h.

The two unknown quantities y_1 and K being determined, the maximum compression Rc of the concrete will be :—

$$Rc = Ky_1 \text{ .... } (20)$$

The compressive stress Rs and the tensile stress R′s will be :—

$$\left.\begin{aligned} R_s &= mK(y_1-d) \\ R'_s &= mK(h-d'-y_1) \end{aligned}\right\} \text{ .... } (21).$$

(*b*) *Compression in Combination with Flexure.*—In this case we know the pressure N and the position of the centre of pressure C, the point of application of the resultant of the external forces. Let us call c the distance of this point from the compression face, this distance being positive if C falls inside the section, and negative in the opposite case. It appears more suitable in this case (it will be said why later) to determine the position of the neutral axis by means of its distance XC=y_2 (*Fig.* 3) from the centre of pressure C rather than by means of its distance y_1 from the compressive face. Therefore the sum of the moments of the elastic forces about C is zero, and we obtain an equation for the determination of y_2 or of the position of the neutral axis x′xc. In the case when this axis falls inside the rib, this equation is the following :—

$$\frac{b'y_2^3}{6} - b\left[\frac{c^3}{2}y_2 + \frac{c^3}{3}\right]$$
$$+ (b-b')\left[\left(\frac{-c+\epsilon}{2}\right)^2 y_2 - \left(\frac{-c+\epsilon}{3}\right)^3\right]$$
$$+ m\omega(y_2+c-d)(-c+d)$$
$$-m\omega'(h-d'-c-y_2)(h-d'-c) \text{ ... } (22).$$

We see that this equation is of the form :—

$$y_2^3 + py_2 + q = c \text{ .... } (23),$$

the numerical coefficients known p and q have the following expressions :—

$$\left.\begin{aligned} p &= -\frac{3b}{b'}c^2 + 3\left(\frac{b}{b'}-1\right)(c-\epsilon)^2 \\ &\qquad -\frac{6m\omega}{b'}(c-d) + \frac{6m\omega'}{b'}(h-d'-c) \\ q &= -\frac{2b}{b'}c^3 + 2\left(\frac{b}{b'}-1\right)(c-\epsilon)^3 \\ &\qquad -\frac{6m\omega}{b'}(c-d)^2 - \frac{6m\omega'}{b'}(h-d'-c)^2 \end{aligned}\right\} (24).$$

The term y_2 missing, the resolution of the equation is more easy and justifies the use of the unknown quantity y_2.

When y_2 is known, the unknown auxiliary quantity K is immediately given by the equation :—

$$\frac{N}{K} = \frac{b'y_2^2}{2} + bc\left(y_2 + \frac{c}{2}\right)$$
$$+ (b-b)'\left[(-c+\epsilon)\frac{1}{2} - \left(\frac{-c+\epsilon}{2}\right)^2\right]$$
$$+ m\omega(y_2+c-d) - m\omega'(h-d'-c-y_2)$$
$$\text{...... } (25),$$

where the second term and N are known.

These formulæ assume the neutral axis to fall inside the rib. If falling inside the slab, or in the case of a rectangular section with base b and height h, it suffices to make b′=b, and we get :—

$$\left.\begin{aligned} p &= -3c^2 - \frac{6m\omega}{b}(c-d) + \frac{6m\omega'}{b}(h-d'-c) \\ q &= -2c^3 - \frac{6m\omega}{b}(c-d)^2 - \frac{6m\omega'}{b'}(h-d'-c)^2 \end{aligned}\right\} (26).$$

Finally, in the case of a slab, to ascertain whether the neutral axis falls inside the rib or the slab, we have only to make $y_2 = -c+\epsilon$ in the first term of equation (23) and in its derivative taken about y_2, then :—

$$\left.\begin{aligned} &(-c+\epsilon)^3 + p(-c+\epsilon) + q \\ &3(-c+\epsilon)^2 + p \end{aligned}\right\} \text{ ...... } (27).$$

If the numerical values of these two expressions are of opposite sign, the neutral axis falls inside the rib; if they are of the same sign the neutral axis falls inside the slab.

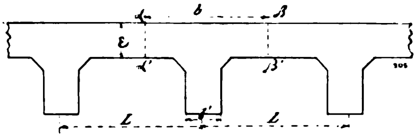
When the unknown quantities y_2 and K are determined, it will be deduced from the first that:—

$$y_1 = y_2 + C \ldots\ldots\ldots (28)$$

for the distance of the neutral axis from the compressed face. Then the unit compressive stress Rc of concrete, the unit compressive stress Rs, and the unit tensile stress R′s of the reinforcements, will be determined by means of equations (20) and (21).

Remarks Dealing with the Design of Slabs.

When a floor is constituted by a slab in combination with ribs (*Fig.* 4), one rib is separated from the whole with two projecting portions of the slab in order to consider only the segment $\alpha\alpha'\beta\beta'$ of breadth $\alpha\beta = b$, neglecting the assistance that this portion of floor may receive owing to its adhesion with the neighbouring parts.



This breadth *b* is to be computed in relation to the depth ε of the slab, to the spacing L of the ribs and to their span L. It is desirable never to exceed for the breadth *b* one-third of the span *l*; nor three-fourths of the spacing of the ribs.

As regards the floor itself, if it has to support concentrated loads between two ribs, two series of reinforcing bars are to be provided; giving, as a general rule, to the smaller a total sectional area per unit of breadth equal to half of that of the greater.

Then, in the calculation of the floor depth ε, the concentrated load may be replaced by a load uniformly distributed on a rectangle having the point of application of this force as centre, its sides parallel to the ribs and its breadth *e* equal to the following depths: (1) that of the slab itself, or ε; (2) that of the embankment and of the roadway; the sides perpendicular to the ribs, are to be spaced apart:

$e + \frac{L}{3}$, (L being the spacing of the ribs).

The load being distributed in such a manner, it is assumed to be supported by a strip of slab, the breadth of which is $e + \frac{L}{3}$ without any assistance from the adjacent portions and consequently by a beam, of which $\left(e + \frac{L}{3}\right)\epsilon$ is the sectional area and L the span.

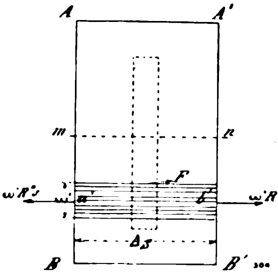
In the case of a slab carried by two right-angled series of ribs, with respective spacings L and L′, the bending moment parallel to the span L may be calculated, *faute de mieux*, by considering only the ribs of which the span is L, and multiplying the result by the coefficient of reduction:—

$$\frac{1}{1 + 2\frac{L^4}{L'^4}}.$$

The bending moment parallel to L′ will be calculated in the same way, substituting L for L′ and *vice versa.*

Adhesion.—To ensure the adhesion between the concrete and the tensile reinforcement, for instance, it will be observed that if in two neighbouring sections AB and A′B′ of a member (*Fig.* 5), spaced

Fig 5.



Δ s apart, the tensile stress of the reinforcement has been found equal to R′s and R″s per unit of area, the total tensile stresses over these two sections will be:—

ω′R′s and ω′R″s.

Supposing, for instance, R″s > R′s, the difference ω′(R″s − R′s), will tend to produce the slipping in its encasing of concrete of the portion Δ s of the reinforcement. Therefore, if the total perimeter of the tensile reinforcements is x′, the adhesive strength per unit of area will be:—

$$\frac{\omega'(R''_s - R'_s)}{x'\Delta_s}.$$

The value of this ratio is not to exceed for the safe adhesive stress prescribed by Article 6.

If stirrups or other transverse reinforcements are sufficiently connected with longitudinal reinforcement so as to prevent any slipping of these latter in casing of concrete, then the shearing stress in the transverse reinforcements along Δ s, or the product of the total sectional area which is in shear by the safe working stress allowed for the metal, is to be deducted from the stress ω′(R″s − R′s), and it suffices that the ratio:

$$\frac{\omega'(R''_s - R'_s) - F}{x'\Delta_s}$$

does not exceed the safe adhesive working stress.

But mere ties connecting the transverse with the longitudinal reinforcement are not sufficient for resisting the force F. These ties are necessary, but their assistance to the adhesion is not to be considered.

Longitudinal Slipping of Concrete in itself and Shearing Stress.—Let us conceive a portion of the member limited by the two cross-sections AB and A′B′ (*Fig.* 5), spaced Δ s apart, and including the longitudinal tensile reinforcement a′b′; *mn* is a cross-section made in the tension area of the concrete that is, between the reinforcement a′b′ and the plane of neutral fibres. Let ω_c = area of that section.

As the tensile stresses of the concrete normally to mB and nB′ are not taken into account, the portion mnBB′ is balanced by the influence of tensile stresses ω′R″s and ω′R′s of the reinforcement and of the longitudinal stress, or shearing stress, along *mn*. Therefore, this stress per unit of area

$$\frac{\omega'(R''_s - R'_s)}{\omega_c} \qquad (a),$$

must not exceed the safe limit allowed for shear.

If transverse reinforcement efficiently resists the longitudinal slipping, it is allowed to take it into account, as stated above, for adhesion.

This stress (a) remaining constant as far as the neutral axis, and decreasing further owing to the effect of pressure, the amount above considered is a maximum.

The amount of the shearing force at any point is otherwise equal to the longitudinal slipping above referred to.

12. *Compression with Flexure.*

Euler's formula, applied with a suitable coefficient, permits the design of a compression member without flexure.

It permits computations of the safe load N not to be exceeded, that may be borne by a member of the length $= l$, hypothetical section $= \Omega$, minimum radius of gyration $= r$, relative to the various axes passing through the centre of gravity (for symmetrical members the radii of gyration about the bending axis or normal to the plane of symmetry are generally to be considered). The expression of N is:—

$$N < \frac{1}{Kt}\,\frac{\varpi^2 E_c \Omega r^2}{l^2}.$$

Ec is the modulus of elasticity of concrete (its average value being one-tenth of the modulus of elasticity of steel), t is a factor of safety and K a coefficient depending on the manner in which the ends of the member are fixed, and having the values as per Table A below.

As regards the factor of safety, the results obtained will be comparable with those given by Rankine's formula for great lengths in admitting:—

$$\frac{E_c}{t} = 1000 R_c,$$

Rc being the safe compressive working stress allowed by Articles (4) and (5) of the Instructions. We then shall have:—

$$N < \frac{1000 R_c}{K}\,\frac{\varpi^2 \Omega r^2}{l^2};$$

or approximately:—

$$N < \frac{1000 R_c}{K}\,\frac{\Omega r^3}{l^2}.$$

III.—Part IV.

The Instructions concerning the practical construction of works and tests, require neither comment nor explanation.

It will be remembered that the reliability of works in reinforced concrete is largely based upon their perfect construction. The accidents which have occurred in the past have been due, as a rule, to bad selection or preparation of materials. Specially stringent supervising is, therefore, to be exercised on the nature and clearness of the materials, on their mixture, the amount of water employed, the ramming and forcing the concrete along and around the reinforcement, and the correct disposition of these latter, etc.

As for tests, they may be simplified in some cases if justified; but it would not be proper to endeavour to save money or trouble if these advantages involve the least risk to the public.

TABLE A.

Methods of fixing the ends.	K	Observations.
One end fixed and the other free ..	4	
Both ends rounded	1	
One end fixed and the other rounded ..	½	If the fixing is imperfect, an average value is to be taken between ½ and 1.
Both ends fixed ..	¼	If one of the fixings is imperfect, an average value is to be taken between ¼ and ½; if both are imperfect, between ¼ and 1.

Reinforced Concrete Bridges.

III.

By W. NOBLE TWELVETREES, M.I.Mech.E.

In no Department of constructional engineering has reinforced concrete been found of greater service than in that of bridge work, and although Great Britain can only show but few examples of reinforced concrete bridges, they can be counted by hundreds on the Continent of Europe, and in the United States. In the present series of articles the author summarises the primary features of the most useful types of reinforced concrete bridges with the view of demonstrating the many forms available for the British designer.—ED.

ALTHOUGH once regarded with a certain amount of suspicion, the combination of concrete and steel has been very largely employed by bridge builders in almost every part of the world, and its use for this particular purpose is by no means unknown in our own country. Various examples have been illustrated in the preceding article, in connection with which the present one should be read as a continuation.

LAKE PARK BRIDGE, MILWAUKEE, U.S.A.

A bridge differing in several particulars from any previously considered, is one across a river at Lake Park, Milwaukee, U.S.A. This structure, of which a half elevation is given in *Fig.* 22, includes approaches, abutment piers and ribbed arch with a span of 118 ft., all of reinforced concrete. The floor slab of the approaches and arch is reinforced by a network of $\frac{1}{4}$ in. diameter longitudinal rods spaced 18 in. apart, and of $1\frac{1}{2}$ in. by $\frac{1}{2}$ in. transverse bars of the Kahn type, spaced 9 in. apart. In the approaches, the floor slab is supported on concrete walls, in which $\frac{1}{4}$ in. diameter bars, spaced 12 in. apart, are embedded to prevent injury to the concrete by the effects of frost. The arch is formed by two ribs of reinforced concrete, 54 in. deep by 12 in. thick, with 9 in. by 9 in. inside flanges added for architectural effect, the arches being braced together at intervals of about 12 ft. by cross walls continued upwards to form part of the pierced spandrils supporting the reinforced floor slab. The reinforcement in each rib consists

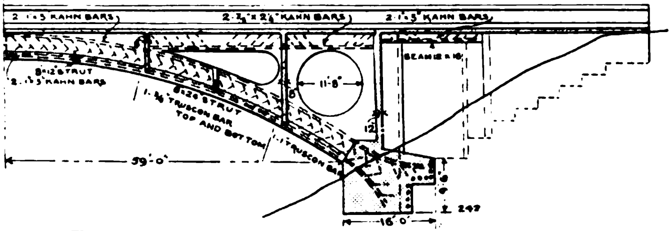
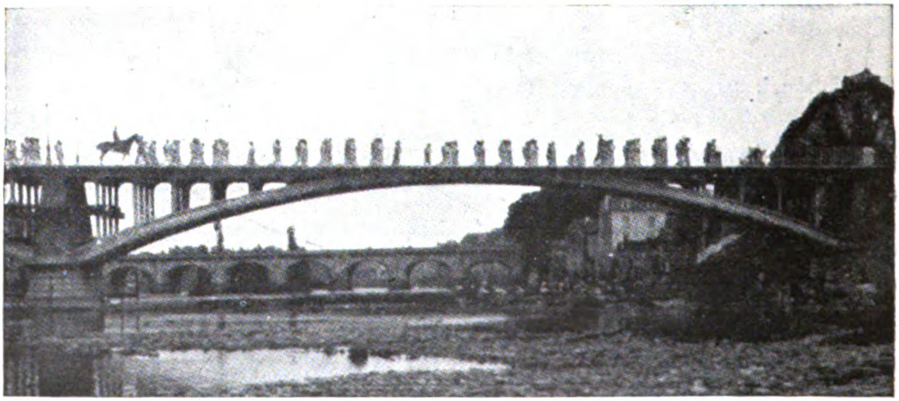


FIG. 22. LAKE PARK BRIDGE, MILWAUKEE, U.S.A.

of four 3 in. by 1 in. Kahn bars, two at the top and two at the bottom, connected by twin buckles. These bars are connected by auxiliary reinforcement, as shown in the drawing, and in addition to them another form of patented bar was used at the top and bottom of the rib for a distance of about 36 ft. from either abutment. The pierced spandrils are also reinforced by 3 in. by 1 in. Kahn bars for the adequate support of the floor slab. The bridge was designed by the Newton Engineering Company of Milwaukee, with Professor F. E. Turneaure as consulting engineer.



FIGS. 23 AND 24. CHATELLERAULT BRIDGE, FRANCE.*

CHATELLERAULT BRIDGE, FRANCE.

One of the most interesting reinforced concrete bridges built on the Continent in recent years is that over the River Vienne in France. *Fig.* 23 is a general view of the structure which includes the longest span genuine arch of reinforced concrete yet built. The foundations, piers, abutments, arches, and decking of this bridge are all designed on the Hennebique ferro concrete system.

The total length of the bridge is 443 ft.; it includes a centre span of 164 ft., and two end spans, each of 131 ft. Each span consists of an arch ring stiffened by four parallel ribs supporting vertical columns carrying the ribbed floor platform, which provides for a roadway 16 ft. 5 in. wide and two footways each 4 ft. 11 in. wide, the latter being carried partly on cantilevers.

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* The illustrations have been kindly provided by Messrs. Hennebique.

Fig. 24 gives a good idea of the arrangement, and shows the light and elegant character of the structure. The arch ribs diminish in thickness from the springings to the crown, where they are only 28 in. thick. The reinforcement of each arch rib consists of round bars parallel with the top and bottom surfaces, and connected by U-shaped stirrups, as usual in the Hennebique system. The reinforcement is continued into the piers, which consist of shells of reinforced concrete with plain concrete filling, and are carried up to the level of the floor platform.

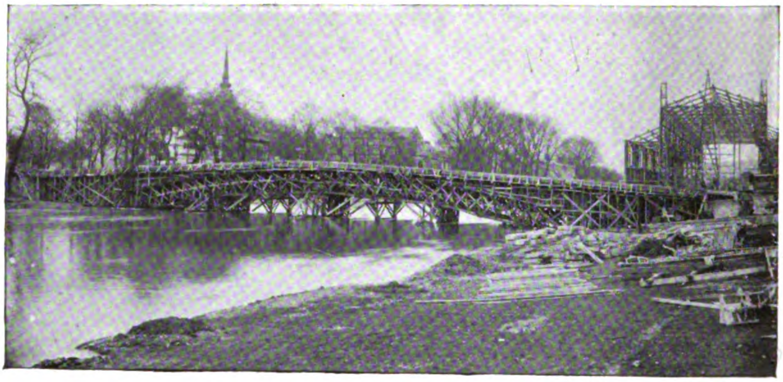
The bridge was designed for a moving load equal to the passage of two files of four-wheeled vehicles, weighing 16 tons each, and a dead load of 100 lb. per square foot on the footways. On completion, in December, 1899, the bridge was subjected to a series of trials under the direction of M. Aubin, an engineer of the Ponts et Chaussées. The dead load tests were conducted in the following manner: Each bay was loaded over its total length, then on each half and then on the middle; the load consisted of moist sand and represented 165 lb. per square foot on the road bed and 123 lb. per square foot on the footways. According to the official report of M. Aubin, the maximum deflections were $\frac{1}{4}$ in. for the arch at the left bank, $\frac{7}{32}$ in. for the arch at the right bank, and $\frac{13}{32}$ in. for the central arch. The main depression of the lateral arches was $\frac{1}{1300}$ of the spans and for the central arch only $\frac{1}{5000}$, and upon removal of the load the arches returned exactly to their original position. The bridge was next tested with a moving load consisting of one steam roller weighing 16 tons, two four-wheeled vehicles, weighing 16 tons each, six two-wheeled carts, weighing eight tons each. As a further test 200 soldiers were marched across the bridge in a body, first at cadenced step and then in double quick time (see *Fig.* 24). Afterwards, the steam roller was driven across the bridge, upon which strips of wood, 2 in. thick had been placed in order to produce a series of jolts. The maximum depression then did not exceed $\frac{1}{9000}$ of the length tested, and no permanent deformation was caused by any of the tests.

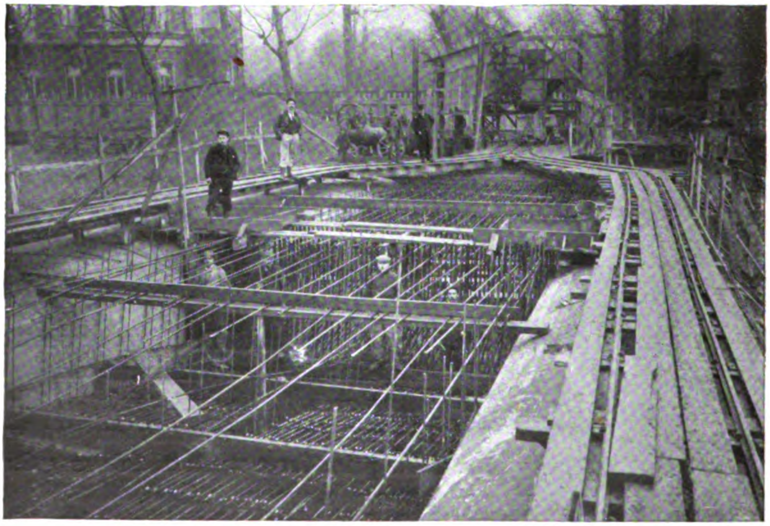
One interesting fact demonstrated by the trials mentioned above was that the load causing deflection in any one of the three arches at the same time produced a corresponding elevation of the adjoining arch. The deadweight of the bridge is only 250 lb. per square foot, and the total cost of construction was less than £8,000, which is an extremely reasonable price for a work of this magnitude.

LA BOUVERIE ISLAND BRIDGE, LIEGE.

The cantilever bridge recently built across the Derivation—the new channel—of the River Ourthe, in Liège, embodies the longest span hitherto constructed on the Hennebique system. The length of the bridge is 260 ft. between abutments, the work including a centre span of 180 ft. and two side spans of 32·8 ft. each. The foundations are formed by groups of reinforced concrete piles, the reinforcement of which is continued into the piers and abutments so that the whole construction is solidly bound together and rooted into the earth. The superstructure may be considered as consisting of two double cantilevers with unequal arms, the shorter arm of each being enabled to counterbalance the longer arm by the weight of the abutment.

The cantilever arms projecting towards the middle of the stream are 2·46 ft. thick at the haunch and 0·5 ft. thick at the extreme end, or point of junction, but the thickness is increased to 1·15 ft. by the floor platforms, which are 7·9 in. thick throughout and monolithic with the cantilever arch for a distance of 41 ft. on either side of the centre. In those parts between the solid construction and the piers, the cantilever arms are connected with the platform by three vertical struts, 7·85 in. thick. The platform constitutes a tension member, and the curved ribs are compression members as required in cantilever design.





FIGS. 25 AND 26. RIVER OURTHE BRIDGE, LIÈGE.

The width of the spans is 18 ft., corresponding merely with the width of the roadway, and to provide for carrying the two 7·4 ft. footways, cantilever brackets project from either side of the platform, making up the total width of 32·8 ft.

Figs. 25 and 26 and the foregoing details are taken from a paper read by

M. Noaillon before the Liège meeting of the Institution of Mechanical Engineers.* *Fig.* 25 illustrates the placing of reinforcement before the deposition of concrete and *Fig.* 26 shows the temporary works used for the construction of the bridge, which was completed in the short period of three months, just before the opening of the Liège exhibition last year. *Fig.* 27 is reproduced from a more recent photograph of the bridge, and indicates in very striking fashion the extremely slender proportions of the bridge and should be a revelation to those who still judge the new structural material by the properties of plain concrete. Examination of this photograph and consideration of the fact that the structure was tested with a moving load of 65 tons ought to convince the most conservative mind that in reinforced concrete we have a material characterised by remarkable strength and elasticity.

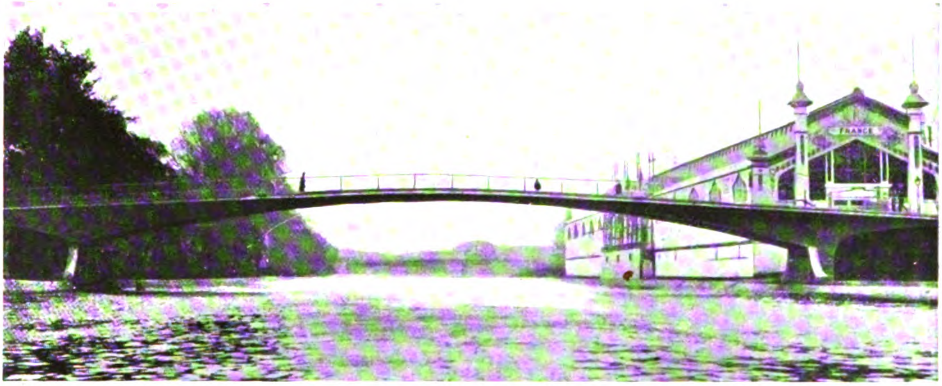


FIG. 27. GENERAL VIEW OF THE LIEGE BRIDGE.†

In some of the foregoing examples of arch construction the design is governed generally by the theory that the direct thrust acting along the line of resultant pressures is borne partly by the concrete and partly by the steel reinforcement, while tensile stresses due to the bending moments which arise from eccentric loading and temperature changes are resisted chiefly by the reinforcement.

Mr. Thacher, and some other engineers mentioned, consider it advisable that the steel should be capable of resisting the tensile stresses without any assistance from the concrete, and without exceeding the elastic limit of the metal. This condition involves increased cost, and is scarcely necessary in cases where the line of pressure is everywhere within the middle third of the arch ring.

The method of designing a reinforced concrete arch is somewhat similar to that employed for a masonry or plain concrete arch. The ring is divided by assumptions into separate sections and the line of resistance determined by the graphical method, the thrust and bending moment at each assumed joint are calculated from the estimated load, and the proportions of the concrete and the steel are settled in accordance with the usual principles of reinforced concrete design.

It will be seen that the great advantage secured by the use of reinforcement is

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* Proceedings Institution Mechanical Engineers, 1905.

† This Illustration has been kindly provided by Messrs. Hennebique.

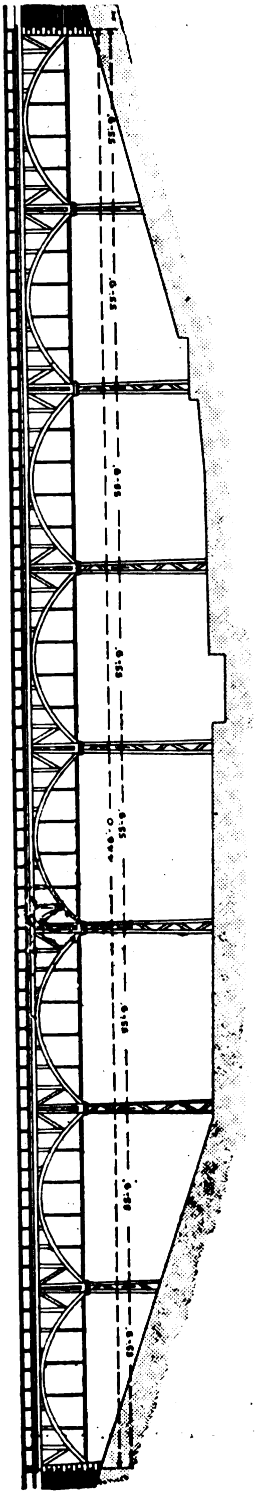


Fig. 28. Guillec Viaduct, France.

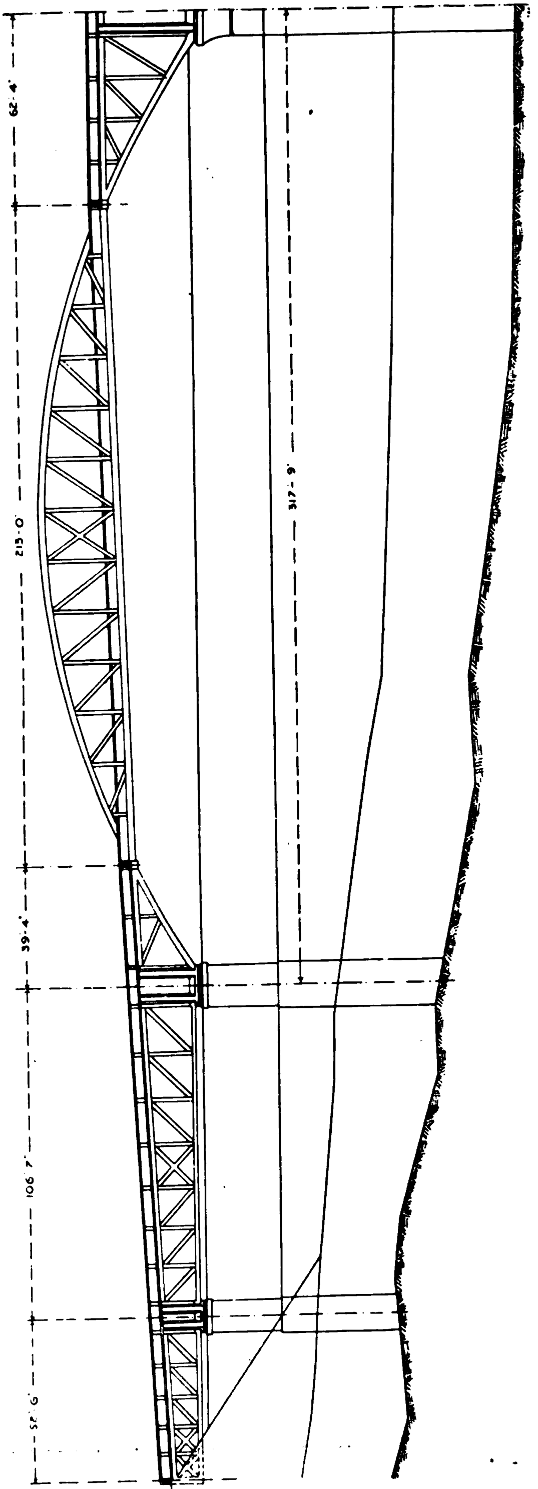


Fig. 29. Fougastel Bridge, France.

reduction of the thickness that would otherwise be necessary for keeping the line of pressure within the middle third of the arch ring. By employing steel the line may pass beyond this limit without involving risk of failure. Consequently, the weight of material in the ring can be largely reduced, with a corresponding reduction of material in the abutments, and much longer spans are practicable than would be possible with ordinary masonry.

THE GUILLEC VIADUCT AND THE POUGASTEL BRIDGE.

These examples are taken together, because they both represent the "Armocrete" system, which so far as compression members are concerned, is based upon the variety of reinforced concrete" devised by M. Considère, Inspecteur-General des Ponts et Chaussées, described by him as "béton fretté," or hooped concrete.

Briefly stated, the essential principle underlying this method of reinforcement is that a spiral winding of steel, about a core of concrete, is placed in tension by the lateral swelling of concrete under compression, and as the ratio of lateral expansion to longitudinal shortening is about as 1 : 2·4, less strain comes upon the reinforcement used in this way than in the form of longitudinal bars for resisting direct compression. In point of fact, M. Considère's exhaustive experiments show that 1 lb. of steel used as a spiral winding possesses the same value as 2·4 lb. of the same material used as longitudinal reinforcement. At the same time, it should be pointed out that the resistance of the spirals to flexure is small, and that for this reason they should be supplemented by longitudinal bars in all compression members.

The Guillec Viaduct (*Fig.* 28), the

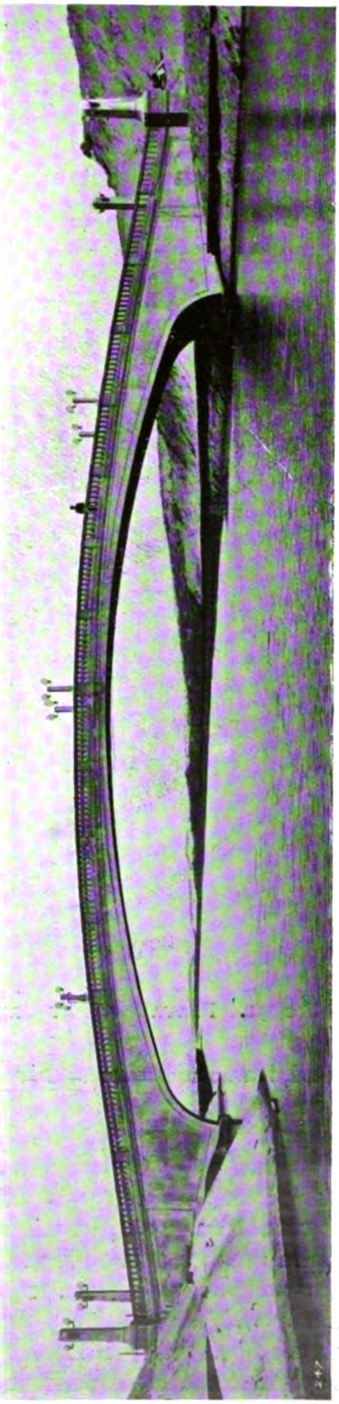


Fig. 30, Playa del Rey Bridge.

construction of which, the author is informed, will be commenced this year, in the Department of Finisterre, France, includes eight bowstring spans of 55 ft. 9 in. each, supported on light latticed piers of hooped concrete, the lower ends of which are wedge-shaped with the object of permitting the piers to swing to the right or the left as the main spans expand and contract under the influence of temperature variations.

The most striking features of the Pougastel Bridge, the construction of which is also to be commenced this year in the Department of Finisterre, are the employment of hooped concrete bowstring girders, with a span of 317 ft. 9 in. and the manner in which the method of bracing usual in steel girder design has been applied to reinforced concrete. (See *Fig.* 29.)

In each of these designs all the tension members are reinforced in the ordinary way, and the compression members in accordance with the Considère system.

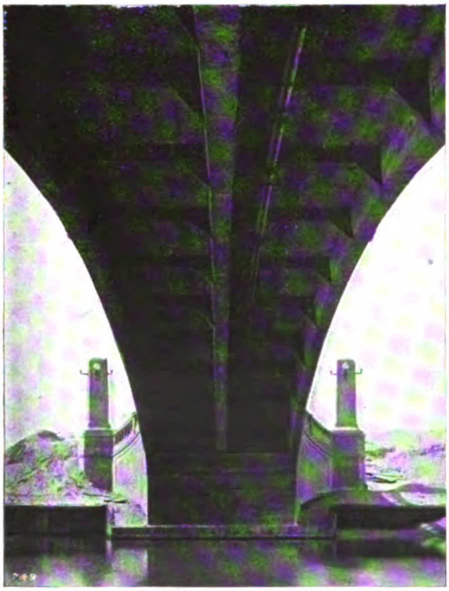


FIG. 31. PLAYA DEL REY BRIDGE.

PLAYA DEL REY BRIDGE, CALIFORNIA.

This bridge, of which a general view is given in *Fig.* 30, has recently been completed for the Los Angeles Pacific Railway Company at Playa del Rey. Although, as will be gathered from *Fig.* 32 it is intended for foot passengers only, the structure is distinctly noteworthy on account of its longitudinal dimensions and bold design. Its total length is 205 ft. 8 in., and the clear span is 146 ft. The arch, which has the rise of 18 ft., comprises three ribs, each 14 in. thick by 2 ft. deep at the crown, including the platform slab, which is 4 in. thick. On account of the unreliable nature of the ground, it was necessary to drive piled foundations for the abutments, which consist of beds of concrete strengthened by steel rail grillages. The ribs are reinforced by four 3½ in. by 2½ in. by ¼ in. angle-bars, one at each corner, connected vertically by 1½ in. by ¼ in. bars, and by three 24 lb. rails one over another. Lateral bracing between the ribs is afforded by reinforced concrete beams 6 in. wide, each reinforced by a 24 lb. rail to the ends of which steel plates are riveted so as to form brackets reinforcing the kneebraces at the connections of the transverse beams and main ribs. *Fig.* 31 gives a good idea of the construction viewed from water level. The spandrel walls and cross walls over the arch ribs are built so as to form chambers filled with loose stones, and the plaftorm slab, moulded at the top of the spandrel and cross walls and incorporated with the arch ribs, is reinforced by a network of ⅜ in. steel bars 5 in. apart and crossing the bridge diagonally. The base and vertical members of the parapet are reinforced by ¼ in. bars, and the upper rail by ½ in. bars. The centering was kept in position for seven weeks after deposition of the concrete. When it was struck a settlement of ⅜ in. was observed, which increased to nearly ½ in. during the following day. The bridge was tested under a load of 3½ tons per square yard with entirely satisfactory results. The designer and builder was Mr. M. de Palo, of Los Angeles.

The author anticipates being able to present an additional example of bridge construction by the same designer in his concluding article.

(*To be concluded.*)

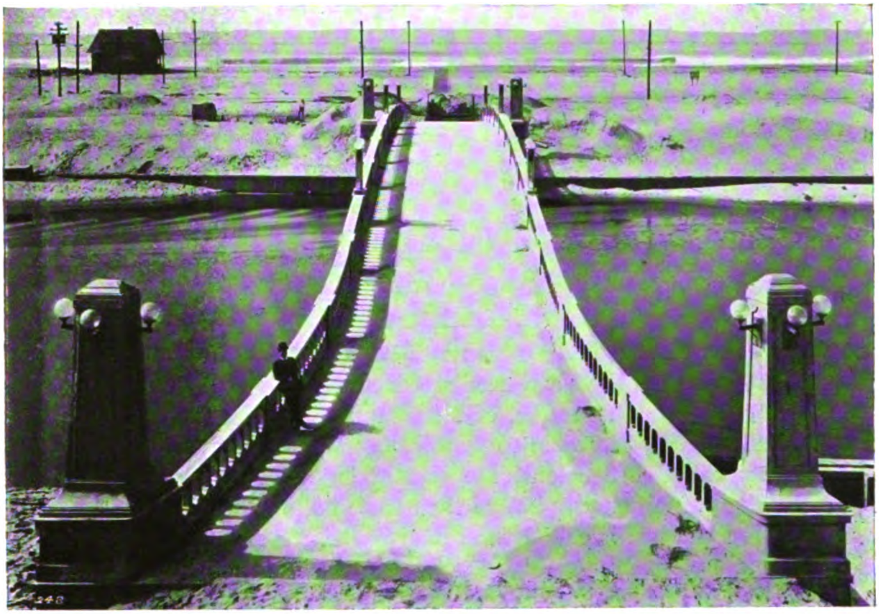
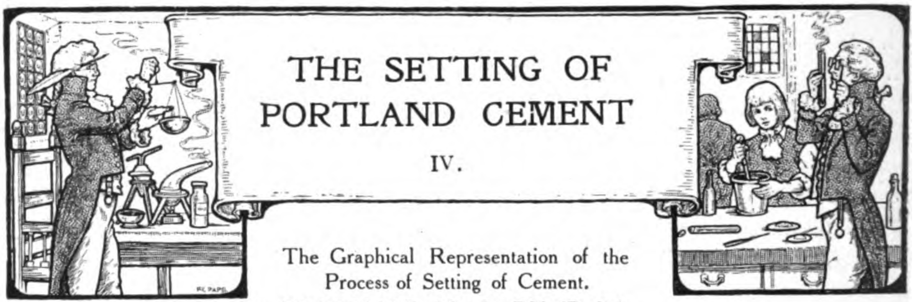


FIG. 32. PLAYA DEL REY BRIDGE.



THE SETTING OF PORTLAND CEMENT

IV.

The Graphical Representation of the Process of Setting of Cement.

By PROFESSOR M. GARY (Berlin).

To all engaged in constructional engineering, and more particularly in the application of concrete and reinforced concrete, the question of the setting of Portland cement is one of the utmost importance. Having regard to this, arrangements have been made by which a series of articles will be presented by well-known authorities at home and abroad, dealing with the question in its chemical and physical aspects, and these various articles will finally be summarised with the view of presenting the more important facts and the consensus of opinion. The attention accorded to the earlier article has encouraged us to extend our list of contributors on this subject to the leading authorities of other countries. Correspondence is invited, as a free discussion of the various arguments put forward will be welcome to all who have this subject at heart.

Regarding the current contribution, the introduction of Professor Gary's method marks a distinct step in advance in the testing of cement. Experience with metals and alloys has shown that critical points (and the initial set of cement may be regarded as such), are recognised with far greater certainty and accuracy by thermometric methods than by any depending on changes in other physical properties, such as hardness. It is to be hoped that the method will find general adoption in laboratories in which the accurate determination of this property is required.

The author, Professor Gary, first presented the data given below as a paper prepared for the International Testing Association.—ED.

THE setting time of Portland cements has hitherto been determined almost exclusively by means of the Vicat needle, the construction of which I may assume to be familiar. When the needle, of 1 sq. mm. circular section, under a given constant load, is no longer able to penetrate completely a pat of freshly mixed cement of prescribed dimensions, the cement is said to begin to set ("initial set"); the time which elapses before the needle no longer makes a "perceptible impression" on the pat is called the setting time. The certainty of the observation is more or less dependent on the subjective perceptions of the observer. Determinations of the setting time of the same cement at different places have consequently often yielded extraordinarily divergent results, and since the setting time of the cement to be used is often specified to an hour, especially by public bodies (a procedure which is not to be recommended) it is important to manufacturers that a method should be found, which under otherwise similar conditions should yield the same values at all places and should be as little as possible affected with uncertainty.

Now it is known that Portland cement sets with considerable development of heat, and the plan suggested itself of observing the course of this heat-development and of drawing conclusions from it as to the course of the setting process. Similar observations of heat changes have been adopted in other industries, as, for instance, in those of fermentation. I made the first experiments of this kind with cement in 1903.

The rubber ring used for the Vicat needle test, closed below by a glass plate, was filled as usual with freshly mixed cement. The filled ring was then placed in a glass vessel, and packed round with sawdust. This vessel was again placed in an enamelled iron pan, wrapped round with felt and covered with a felt lid (*Fig.* 1). A thermometer was passed into the cement through the felt lid and its readings taken at short intervals.

If the observed rise of temperature is plotted on squared paper as ordinates with the time in hours as abscissæ, curves such as those of *Fig.* 2 are obtained The figure contains the temperature curves for two cements, I. and II., both quick-setting, giving a setting time of less than half an hour by the needle test. The setting times determined with the needle are indicated in *Fig.* 2 by arrows. Quick-setting cements were designedly chosen in this case, in order to compress the process somewhat, and at the same time to allow of the determination of the influence of different additions of sand on the course of the setting.

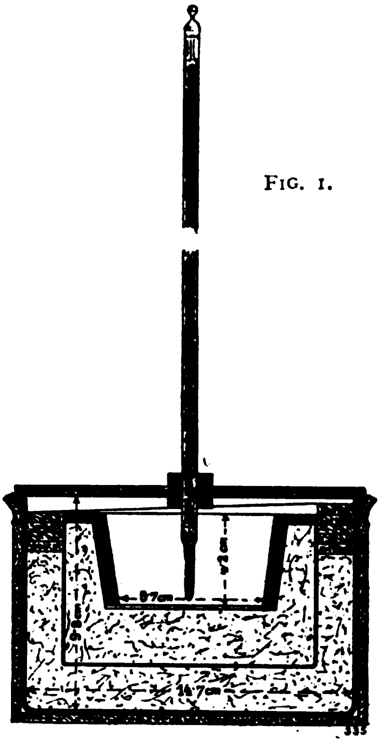


FIG. 1.

With both cements I. and II. the temperature rises rapidly and then falls almost as rapidly. The highest point of the curve marks almost exactly the time which has been regarded by custom as the setting time of the cement.

The cements were mixed with one, two, three, five, and eight parts of normal sand, and the way in which the setting time was modified by the addition of sand was observed. It was then found that with cement I. the addition of even eight parts of sand produced no marked retardation of the setting. That will be understood readily. The quick-setting cement hardens so energetically and with so great a development of heat that even portions between the sand grains set without being cooled by the separating particles of sand. The "setting times" of all the mortars made from cement I. are thus found to lie on a straight line (dotted in the figure). It is the line joining the summits of the curves. The second quick-setting cement II., which gave a smaller development of heat, became much slower on addition of sand; the line connecting the summits of the temperature curves is with this cement curved, and with increasing additions of sand approaches the horizontal.

An effect is to be noticed with this cement which is almost general with slow-setting cements. Many of these, especially when fresh, show a rapid increase of temperature shortly after mixing, the curve then falls somewhat, and after a time rises again more or less rapidly. The lowest point of the curve coincides, according to the observations hitherto made, with the point of "initial set" in needle tests, and the highest point of the curve indicates the setting time, apart from the unavoidable errors of the needle test.

Further observations in this direction showed that every cement has a quite characteristic curve.

In order to show that the changes in setting time which many cements undergo on storage can be determined with certainty by observation of the temperature curves, special experiments were instituted, the results of which are given in

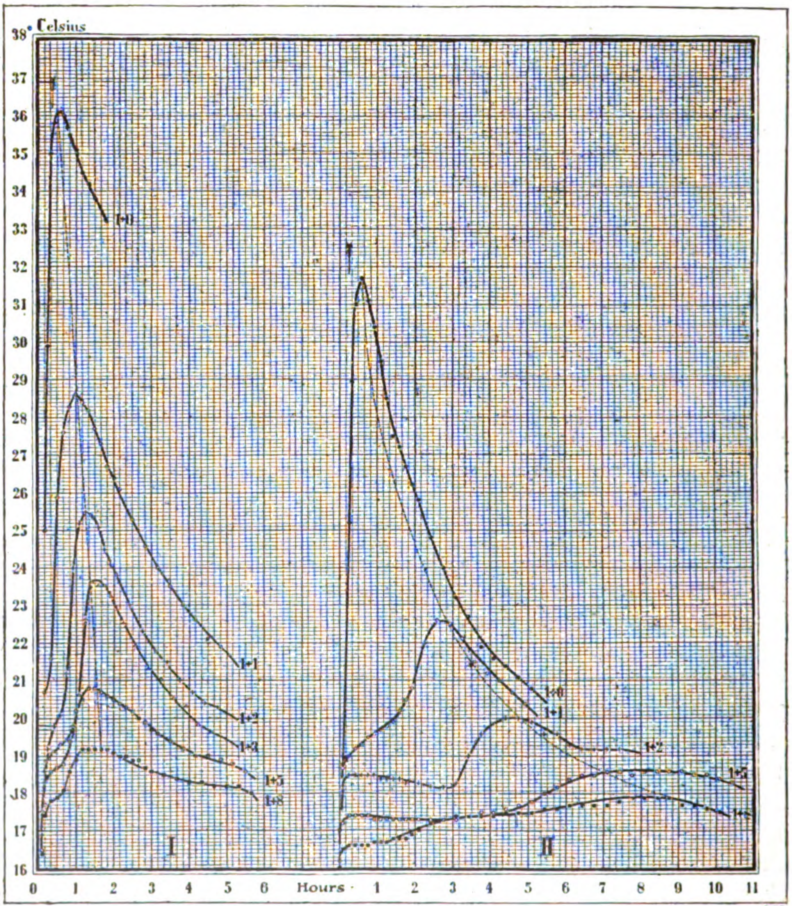


FIG. 2.

Fig. 3. This represents a cement which, when fresh, set in 7 hours by the needle test, but in 8–9 hours as indicated by the curve. Unfortunately, the first curve was not followed to its end. The stored cements, however, were observed until the temperature again fell. It will be seen that the cement, after being stored 28 days, only began to set in 12¾ hours, and was completely set in 13¼ hours. After further storage the setting became more rapid, so that after 42 days it set in 11¾ hours, and after 56 days' storage in 10½ hours. Possibly, it returned ultimately to its initial value. The observations were not continued further, as the taking of the thermometer readings is exceedingly tedious and troublesome.

This suggested the idea of recording the temperature curve photographically. The first apparatus was constructed by Fuess, of Steglitz, to the design of Prof. A. Martens. It consists, as shown in *Fig.* 4, of a small camera, closed above with a leather bag, and containing an ordinary alarum clock. The spindle of this clock carries, instead of an hour hand, a brass drum, to the outside of which sensitised paper is attached. On opposite sides of it two thermometers, divided into 1-10th deg., are fixed, enclosed in brass cases with only a narrow slit in front of the mercury column. A ray of light passes through several diaphragms, and through this slit on to the mercury column, and throws its shadow on to the sensitised paper. The bulb of the thermometer is enclosed in a thin copper foil sheath, filled with mercury, in order to allow of its withdrawal from the cement without injury, and this is inserted in the cement. When the drum and sensitised paper have been placed in the camera, and set to the zero line, a mirror is placed in front of the diaphragms so that a beam of light enters the camera. The drum turns once on its axis in 24 hours, and the shadow of the mercury column appears on the paper as an area with a curved upper boundary following the rise and fall of the mercury. The apparatus allows two curves to be recorded simultaneously, provided that the setting of each cement is complete in 12 hours.

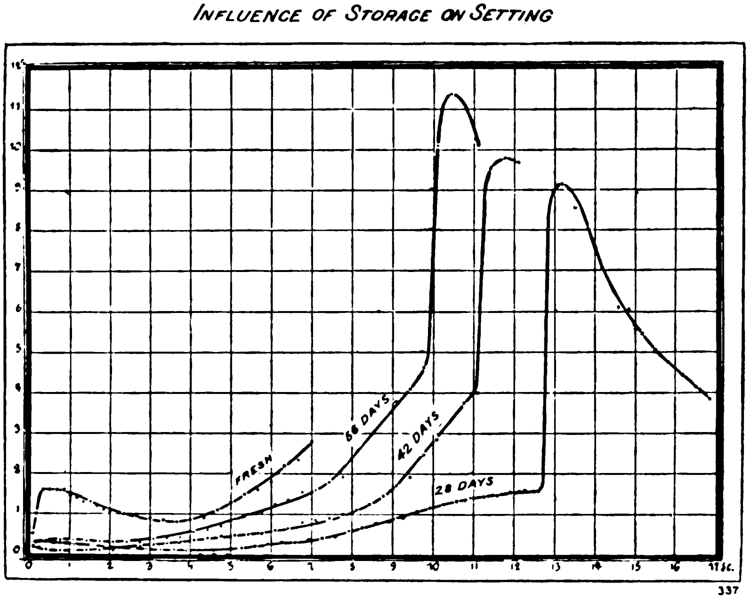


FIG. 3.

Fig. 5 shows four curves taken in this way, representing the setting of one and the same cement mixed with varying quantities of water. When 26·5 per cent. of water, the proportion usually adopted as the standard, was added, the cement was quick-setting (see the uppermost curve), taking only ¼ hour to set. With 30 per cent. of water it still set rapidly, taking ½ hour. With 34-35 per cent. of water, although some action took place within half an hour, it only set after a much longer interval, namely, about 6 hours, as will be seen from the third and fourth curves. Such information respecting the changes in the whole setting process can never be obtained with such clearness and certainty with the Vicat needle.

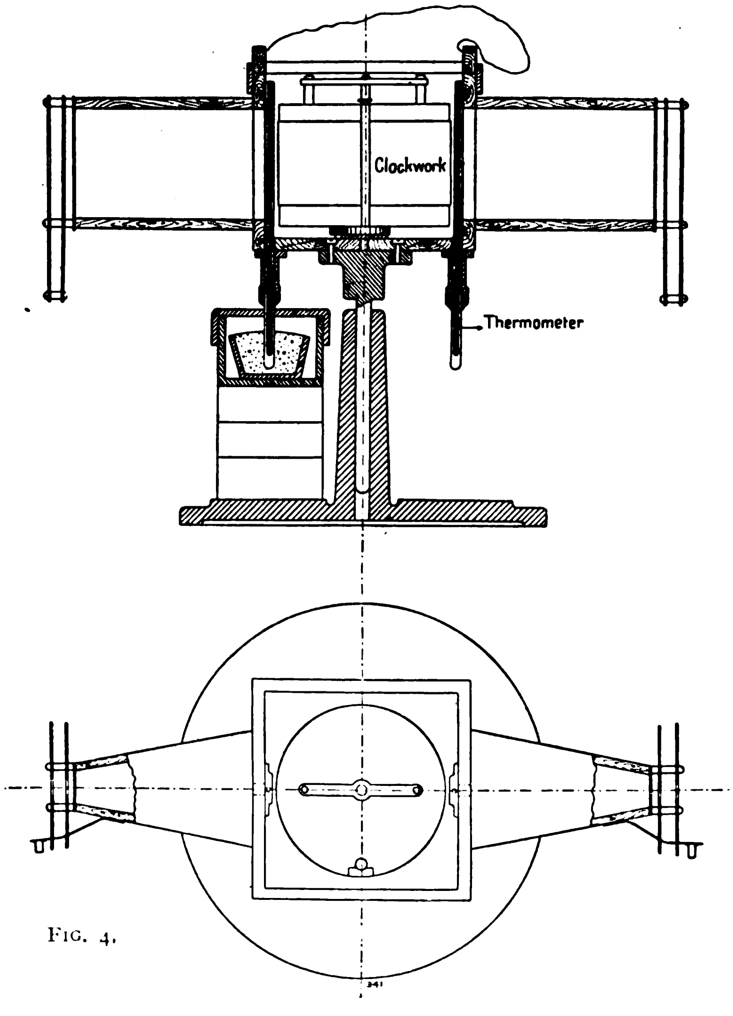


Fig. 4.

Since the Fuess apparatus proved to be somewhat inconvenient in practice, a second apparatus was constructed by the firm of C. P. Goerz of Friedenau to the author's design, advantage being taken of the experience already gained. The principle was the same, but the apparatus allowed the use of flat, sensitised plates of commercial size (stereoscopic plates 18 by 9 cm.), which facilitate handling in the dark room and make it possible to make reproductions of the image at pleasure.

The apparatus is represented in *Fig.* 6.

The camera now rests on three supports. At one end it carries the thermometer in a brass sliding case with a narrow slit, in front of which an ordinary lamp stands as source of light. A screen bent in a semicircle protects the cement and thermometer from radiations. The beam of light, after passing over the mercury column, is thrown by a lens on to the photographic plate contained in a dark slide, which is traversed past the camera in 12 or 24 hours at pleasure.

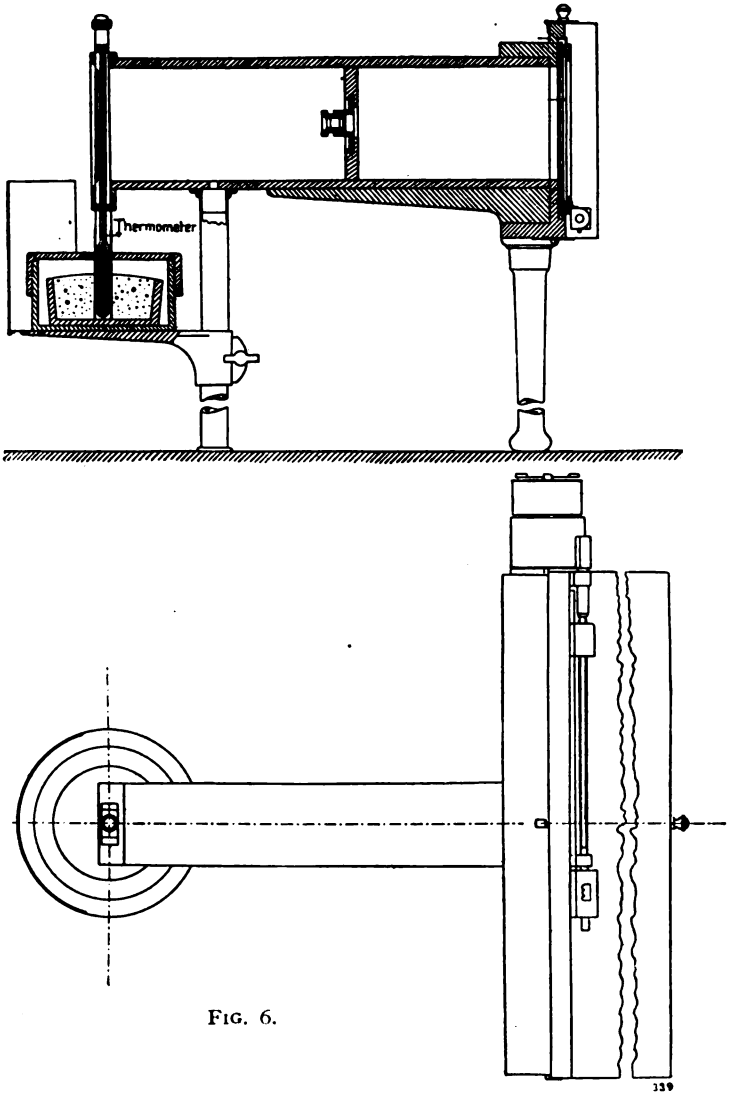


FIG. 6.

The dark slide is readily removable, and the manipulation of the apparatus is simple and certain.

After developing the negative, a screen of ordinates with time as abscissæ, ruled on a gelatin plate, is laid between the negative and the printing paper. (The graduation of the thermometer in degrees is recorded on the plate automatically.) In this way any number of copies may be obtained, on which the initial and final set may be read off directly.

In *Fig.* 7 four curves taken with this apparatus with cements setting within 24 hours are represented. The curves have been traced from the photographs and superimposed. They show how differently various cements behave during setting. The experiments with this apparatus are not yet concluded, but have already yielded many valuable conclusions as to the characteristic peculiarities of certain cements.

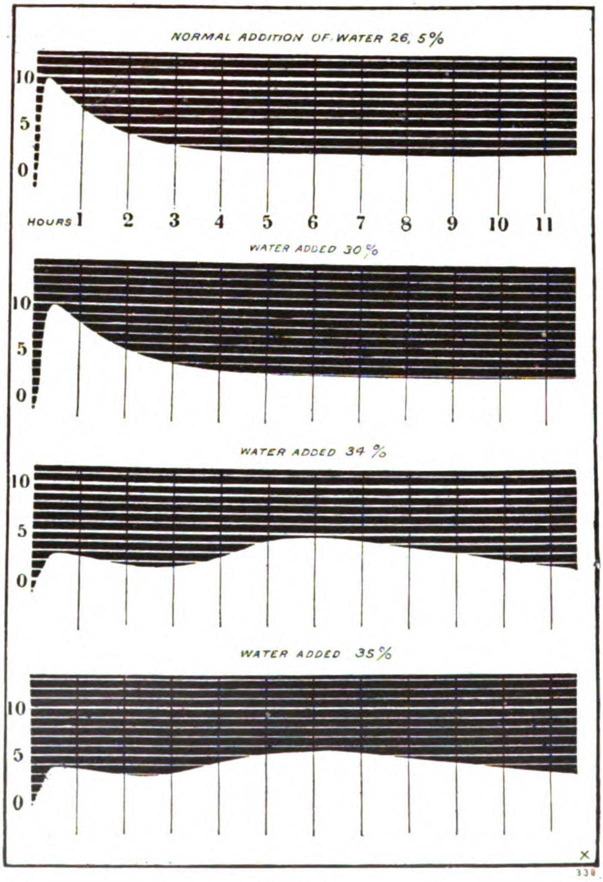


FIG. 5.

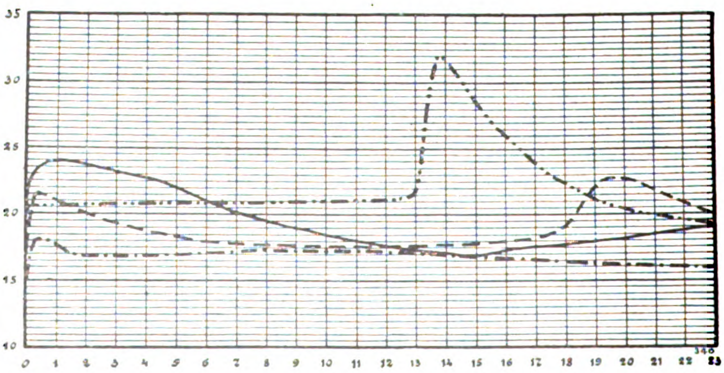


FIG. 7.

WATERPROOFING CONCRETE ON FORTIFICATION WORK IN THE UNITED STATES.

By EMILE LOW, M.Am.Soc.C.E.

In previous numbers we have dwelt with such practical matters relative to concrete construction, as for instance, the question of hair cracks, or the question of frost.

In the current issue waterproofing is our subject and in presenting the following abstract of a Report by the Chief Military Engineer of the United States Army, we hold we are putting forward not only most valuable information of an authentic character, but also data which should be of every day use to the majority of engineers in official or private practice.

We are, however, somewhat surprised that the "Vulcanite roofing," which has made such headway in this country, and is even used for roof tanks and roof gardens, should apparently not have been introduced in the military works of the United States. When genuine "Vulcanite" material of this description has been carefully laid by experienced men during the past ten years the results have been most satisfactory. The difficulty with us, however, is to prevent economically inclined contractors substituting spurious 2-ply tarred paper, referred to below, instead of getting the genuine material.—ED.

DEFENCES OF THE COAST OF MAINE.

To stop leaks through concrete in old work the cracks and seams on the top surfaces were caulked with oakum and elastic cement or elastic cement alone, or the surfaces were covered with one or more coats of preparations of oil and naphtha or asphalt and naphtha. Two makes of elastic cement were used and are about the same as the brand known to the trade as slaters' cements. These cements are supposed to meet changes of temperature without cracking.

In damp-proofing floors of new work two layers of 2-ply tarred paper were put down on a roughly-finished concrete floor about 6 in. below the true floor, with a coating of coal-tar pitch above, beneath and between the layers of paper.

To make the roofs of rooms and galleries in new batteries waterproof the top of the concrete has been covered with 16 oz. sheet copper in several instances. Hot coal-tar pitch has also been applied to vertical concrete surfaces against which sand fill is to be deposited.

BATTERY BLAIR, FORT WILLIAMS.

A number of efforts have been made to stop leaks in the rooms and galleries between the loading platforms, being evident breaks or failures in the waterproofing. The top finish of the platforms, about 6 in. thick, rests immediately on the waterproof course and was put on in entirely separate concrete blocks, about 5 ft. square. A coating of "stone liquid" was applied to surfaces where the most trouble was found, but the benefits were not lasting. "Stone liquid" seems to be a mixture of a heavy oil and naphtha and is very expensive. A mixture of hard boiled linseed oil and naphtha in equal proportions was afterwards used in place of the "stone liquid."

The seams in platforms were first poured with a heavy oil and caulked with oakum, driven in with a heavy caulking tool and mallet, the top of the seam being filled with elastic cement well pressed down. After a heavy thaw it was found that the oakum had absorbed water, swelled, and become loose, and the leaks again appeared. The oakum was removed, the seams enlarged, and after being given a coating of linseed oil, were filled with elastic cement well pressed down.

ELECTRIC POWER-HOUSE, FORT WILLIAMS.

The concrete roof of this house, which showed several bad leaks, has been treated in the same manner as Battery Blair, above referred to, and in addition was given a coating of E-pure asphalt and sand. This is a mixture of asphalt and naphtha, and as it dries very quickly one man applies it with a brush and another follows closely with a thin coating of sand. This was also a failure, both in stopping leaks in the seams and in causing the asphalt to adhere firmly to the concrete. The same results were observed at Battery Daniels, Fort Levett.

ELECTRIC POWER-HOUSES AT FORT McKINLEY AND FORT LEVETT.

The roofs of these houses are of concrete, 4 ft. thick, and were built in sections separated transversely. The planes of separation between the blocks were of course, sources of leakage, and as a temporary expedient for the winter these seams were covered in the fall of 1903 with strips of prepared roofing paper fastened to the concrete with liquid cement furnished with the paper. This answered the purpose quite well, except that while removing snow at Fort McKinley, the paper was also removed in several places, thus causing leaks. Early this spring the strips of roofing paper were removed and the seams cut and filled with elastic cement, as in the case of Battery Blair at Fort Williams. This stopped the leaks, except during two very heavy summer rains, when the water came through in several places. The seams have again been filled with elastic cement well pressed down, and the results have been satisfactory up to the present time, but the prospects of stopping the leaks permanently by this method do not seem promising.

At practically all of the emplacements. where there was any indication of leakage the platforms and parapets have been treated with linseed oil and naphtha, but only in one or two instances has it seemed to do any good. The same may be said of caulking seams with oakum and elastic cement or elastic cement alone.

DEFENCES AT EASTERN ENTRANCE TO LONG ISLAND SOUND.

Linseed oil, sprayed on concrete parapets, was used last year for making the surface non-conspicuous ; this year it has been somewhat extensively applied, and it is believed with good results, for waterproofing as well as surface colouring of parapets and outside vertical walls. For the waterproofing raw oil is mixed 3 to 1 with naphtha or gasoline and well brushed in, 2 to 4 coats are applied according to the porosity of the concrete and until the small air bubbles disappear ; after which a coat without the penetrating " thinner " is applied. It is thought that this water proofing should not be applied to concrete less than a year old. A number of samples of different mixtures of coal-tar or petroleum basis have been tried in different ways for painting or coating parapet surfaces. The best of these is Durable Roof-Leak, made by the Elliott Varnish Co., New York, and sold in small lots at $1 per gallon. " Hydrolene B," as prepared for the purpose by the Sun Company, Philadelphia, is next in order of merit. The Roof-Leak penetrates the concrete a little, adheres well, forms a continuous coat and of enough thickness for sanding. It is not yet known if the coating will stand low temperatures without cracking or peeling off.

DEFENCES OF NEW YORK.

In continuing work of damp-proofing emplacement rooms, interior linings have not been further constructed, but all experiments have been directed toward excluding dampness by external applications. These applications have been straight run coal-tar pitch and sand, asphalt paints, or solutions of asphalt in naphtha and sand, and boiled linseed oil. In some cases, as at Fort Totten and Fort Hancock, larger cracks had been previously filled with roofing pastes, such as Callahan's cement, which pastes had not been entirely satisfactory. At Fort Totten the superior crests of emplacements Nos. 1 and 2 were treated with hot coal-tar pitch and sand; the cracks, where not previously filled with roofing paste, were cleaned out and filled with the hot tar, each coat being well sanded over until the tar would not stick to a man's shoe when walking over it. Additional sand was placed on warm days wherever the tar showed too soft, or a tendency to run.

Applications of Hydrex compound, which much resembles coal-tar pitch, were also made in similar manner at Fort Schuyler, the compound having been softened somewhat by an admixture of petroleum residuum to make it better adapted to flow into the cracks, with similar results. In all cases marked improvement, if not complete success, attended these experiments, but it is evident that the material must be applied at least once a year to give satisfactory results.

At Fort Wadsworth, Batteries Emory, Upton and Barry have for years been extremely wet, and many atempts to better the conditions by filling cracks, etc., have resulted in failure. During the autumn of 1903 the entire superior slopes, the loading and gun platforms were painted two coats (each sanded) with E-pure asphalt roofing cement, the joints and cracks having first been cleaned out and filled with the material.

This paint, being a solution of asphaltum, or bitumen in naphtha, must be used before the naphtha evaporates, otherwise it will not stick to concrete. It is best to take it from the barrel through a molasses gate, as needed, and apply it at once without heating. As fast as it is laid on, sand must be applied, otherwise the rapid drying of the paint will leave a glossy surface; the sanded surface is satisfactory for concealing the battery.

At Fort Hancock several emplacements, where leakage was very bad, have been treated with Hydrex roofing paint and sand, the large cracks having been first filled with Callahan's roofing paste. This paint is similar to E-pure asphalt paint, and must be similarly applied.

All recent batteries have been waterproofed with layers of paper and asphalt, and are quite free from leaks. Batteries now under construction are being damp-proofed with straight run coal-tar pitch, laid on hot, upon from three to five thicknesses of roofing felt. The coal-tar pitch and Hydrex compound, a similar substance, seem to resist the salts dissolved from the concrete better than asphaltum compound and seem to be growing in repute compared with asphaltum for waterproofing.

DEFENCES OF HAMPTON ROADS, VIRGINIA.

This battery was constructed of Rosendale concrete in 1896–7. Its upper surface was sloped for drainage, plastered with cement, and afterwards coated with asphalt before being covered with sand. In spite of this, however, the rooms and galleries were very wet, mainly from seepage water. This water in passing through the concrete became impregnated with carbonates which were deposited in the shape of stalactites and stalagmites, which were numerous.

DAMP-PROOFING BATTERY BRUMLEY, FORT SCREVEN, GA.

This battery was built in sections, with vertical planes of weakness. The magazines were damp and passages wet at all times. Outside waterproofing, as applied lately, *i.e.*, during the past fiscal year, has proved very satisfactory, and the battery is now practically dry. The method employed was as follows :—

The crack between the parapet wall and the apron was filled with hot insulatine, and the cut-off surface of the apron, the groove, and exposed face of parapet wall were painted with asphalt, applied hot. The parapet fill along the entire front of the battery was thrown back down to the toe of the apron, the concrete was dried, cleaned off and then waterproofed with insulatine, applied hot. Care was taken to see that the surface was thoroughly covered. All cracks in the horizontal surface of the concrete were cut out 1 in. wide and ¾ in. deep (some large cracks were cut wider), cracks cleaned out and hot asphalt mixture poured in and ironed down smooth with the surface of the concrete. After the cracks were finished all of the exposed horizontal surfaces of the concrete were painted with two coats of boiled linseed oil and lampblack, applied hot. All vertical surfaces were painted two coats of plain boiled oil and then one coat of slate colour (lead, oil and lampblack). The concrete should be dry and the weather warm when the oil is applied. Later, one coat of tar paint was applied to the parapet surface. This coal-tar paint was composed of coal tar, asphalt and coal oil, mixed in the following proportions, viz. :—

Coal tar : 4 gallons ; asphalt : 1 gallon ; and coal oil : 1 gallon

If any cracks develop after the first coating it is evident that the quantity of asphalt in the mixture is too great, and in other applications should be reduced. This should be allowed to dry for a time, and if it remains sticky, should be sanded. The sand gives it a colour approximating that of the surroundings.

DEFENCES OF THE WEST COAST OF FLORIDA AT KEY WEST AND TAMPA.

During the fiscal year emplacements for 6-in. and 3-in. guns have been constructed at Key West and Fort Dade. In all these batteries the rooms are in traverses covered with sand. The dampproof course is between the concrete and the sand. At Key West asphalt mastic was used, as a quantity of this material was on hand. The top of the concrete was covered with smooth plaster, proper slope being given for drainage. Above this the asphalt was placed in two layers, making a total thickness of about ¾ in. The composition of the asphalt was as follows :—

Rock asphalt mastic : 440 pounds ; Coal-tar : 3 gallons; and siliceous sand : 5 gallons.

After hardening, this was covered with sand. At Fort Dade, Hydrex felt was used for the dampproof course. The top of the concrete was covered with smooth plaster and given a proper slope for drainage. A double layer of Hydrex felt was then applied, the strips of felt being lapped three or more inches and coated with Hydrex cement. The joints of the second course were placed midway between those of the first course. The upper surface of the first course was entirely coated with Hydrex cement before the second course was placed over it.

At both Key West and Fort Dade the vertical walls were plastered after the forms were removed. Before plastering, the surfaces were thoroughly saturated with water, then a coating of thick grout was brushed in. After the grout had attained its initial set the plaster was applied, firmly pressed into place, and floated to a smooth surface. The vertical walls retaining sand fill were given a thorough coating of hot coal-tar. All rooms are perfectly dry.

The Working Drawings of a Reinforced Concrete Grain Silo at Lissa (Prussia).

Requests having reached us to reproduce from time to time actual working drawings of reinforced concrete work that may prove instructive both in respect of design and draughtsmanship, we present the working drawings of a new German Grain Silo. We are indebted for the general illustrations to "BETON UND EISEN," as also for certain particulars, whilst the actual four working drawings and additional particulars have been kindly put at our disposal by the contractors.—ED.

A REINFORCED CONCRETE GRAIN SILO OF 7,000 CUBIC METRES CAPACITY.

THIS silo was constructed in 1904–1905 for Messrs. Schneider and Zimmer's mills at Lissa, by the Lolat-Eisenbeton Company, of Glogau. The soil conditions were extremely unfavourable, being clay soil with water to within 0·80 metre of the surface; all other buildings therefore had to be carried down, at great cost, to solid earth at a depth of 8 metres. In order to avoid such expensive foundation work, Herr Lolat proposed to carry out the entire construction above the water level, and this daring arrangement, considering the soil conditions, has proved brilliantly successful. It is a notable triumph of reinforced concrete.

The owners not requiring the space beneath the bins, it was possible to distribute the load over a number of points, and to make the sill thin, being vaulted between beams 55 cm. thick. The fourteen bins, arranged in two rows, are carried on outer concrete walls 30 cm. thick, slightly reinforced, the middle wall being 20 cm. thick, and more strongly reinforced; between the two stand a double row of columns of the sizes indicated in *Fig.* 2. On account of the large number of supports, the bottoms of the bins are only 15 cm. thick, although they are calculated to carry the entire contents, no allowance being made for friction on the sides of the bins. The bins being so large, horizontal ribs became indispensable, and their vertical distance apart was so chosen that the walls could retain the constant thickness of 12 cm. The principles of calculation adopted were those given in the Beton-Kalendar for 1906 (Pt. 2, p. 101). The walls were considered as members fixed into the horizontal beams, these being fixed into the vertical supports.

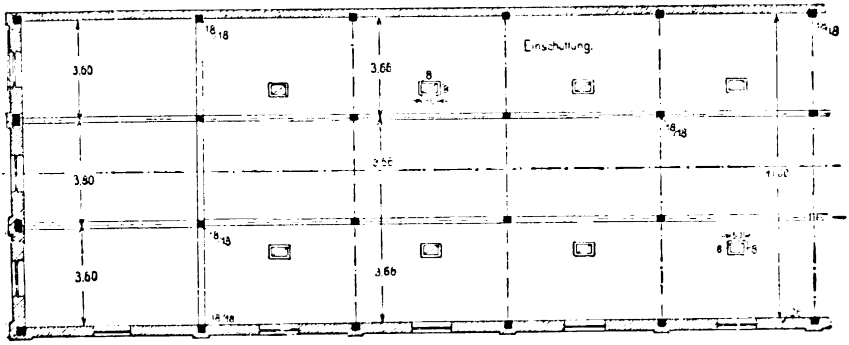
The yielding of the beams was neglected on account of their great stiffness. The loading of each is then composed, as shown in the sketch (*Fig.* 3), of a uniform and a triangular load, so that the moments—

$$M_n = \left(\frac{p_n}{12} + \frac{p_{n+1}}{30}\right) l^2_{n-1}$$

$$M_m = \left(\frac{p_n}{24} + 0{\cdot}0214\, p_{n+1}\right) l^2_{n+1}$$

$$M_{n+1} = \left(\frac{p_n}{12} + \frac{p_{n+1}}{20}\right) l^2_{n+1}$$

may be employed. The external walls were reinforced on one side, the separating walls on both sides.



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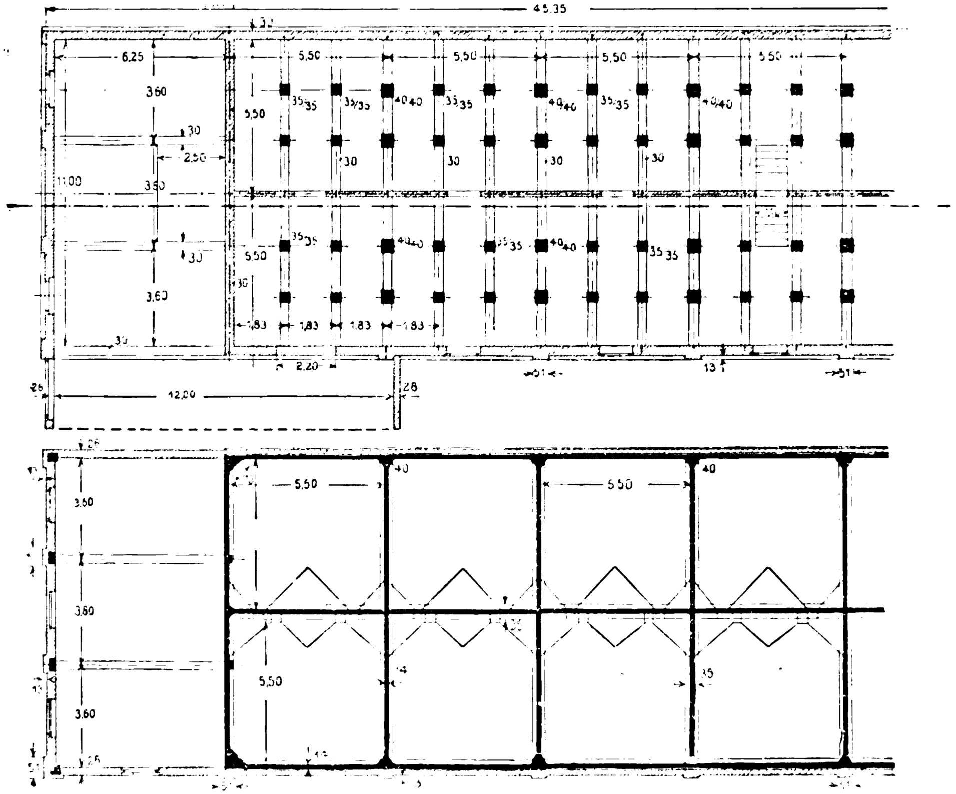

PLANS GH. AND LM.
Figs. 1, 2 and 3.

In order that the silo should harmonise externally with the adjoining buildings it was faced half-brick thick with bricks.

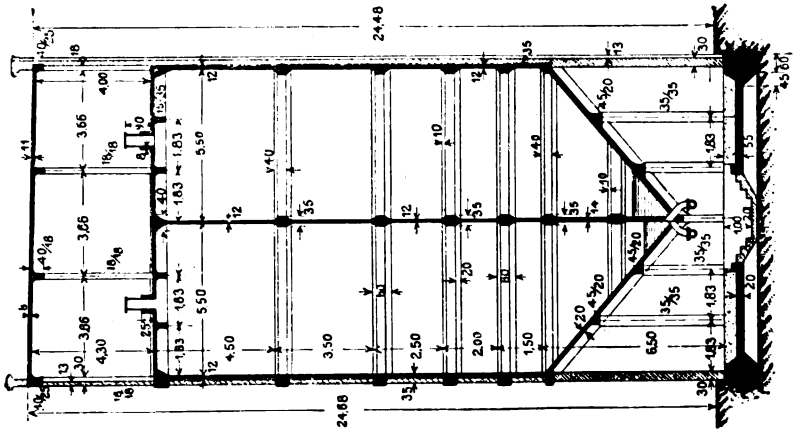

Fig. 5. Section on CD.

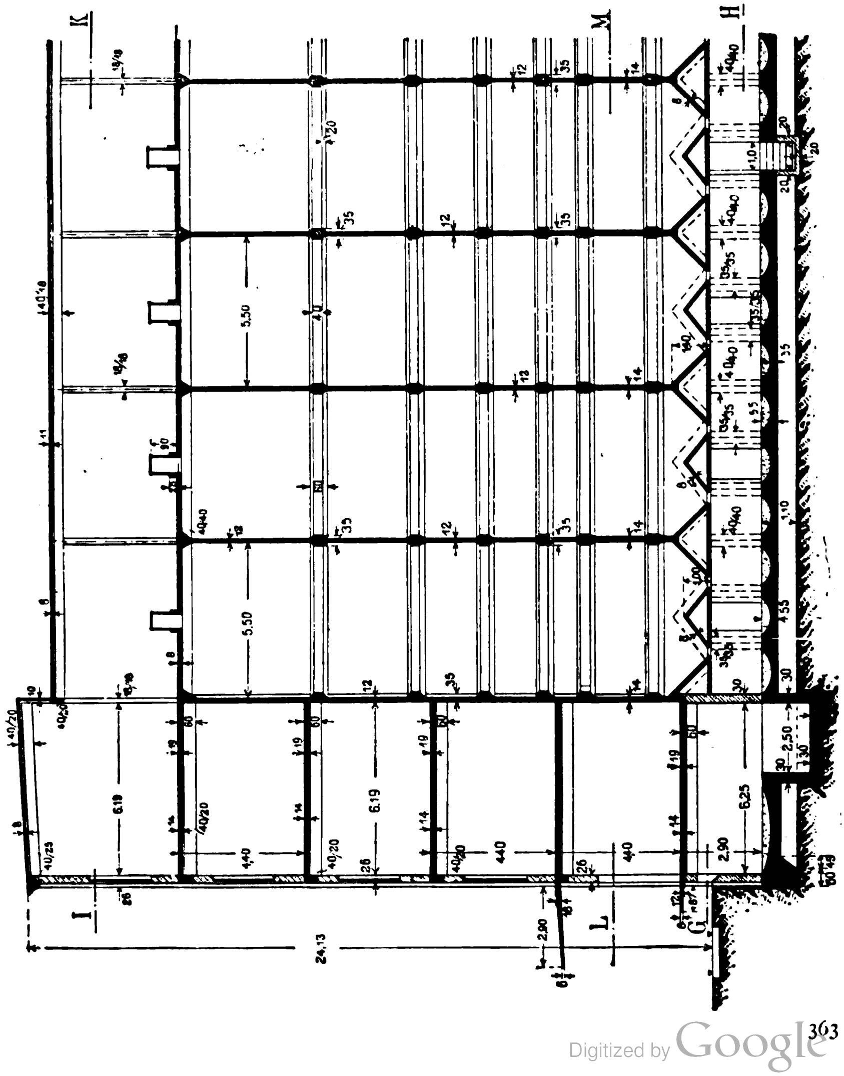

Fig. 4. Section AB.

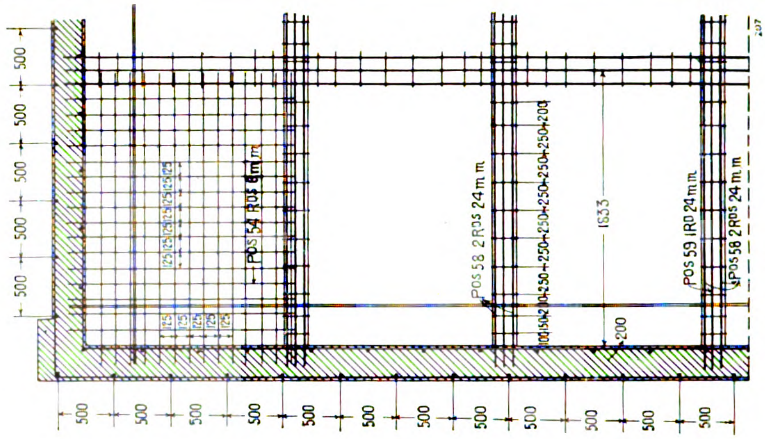
500
125
POS 54 RDS 8 mm
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FIG. 7.

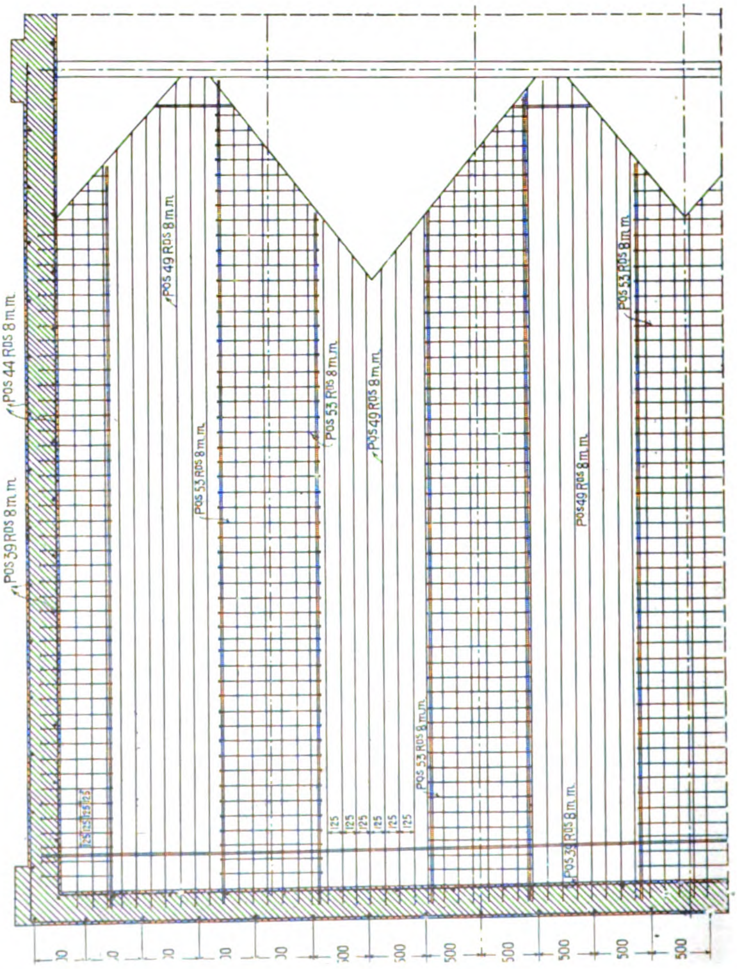
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FIG. 6.

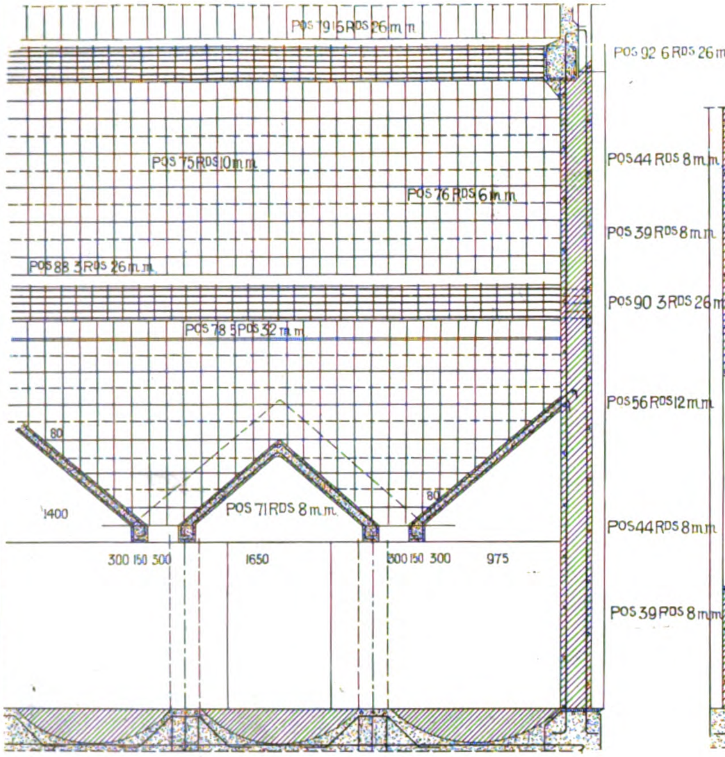


Fig. 8. Cross Section.

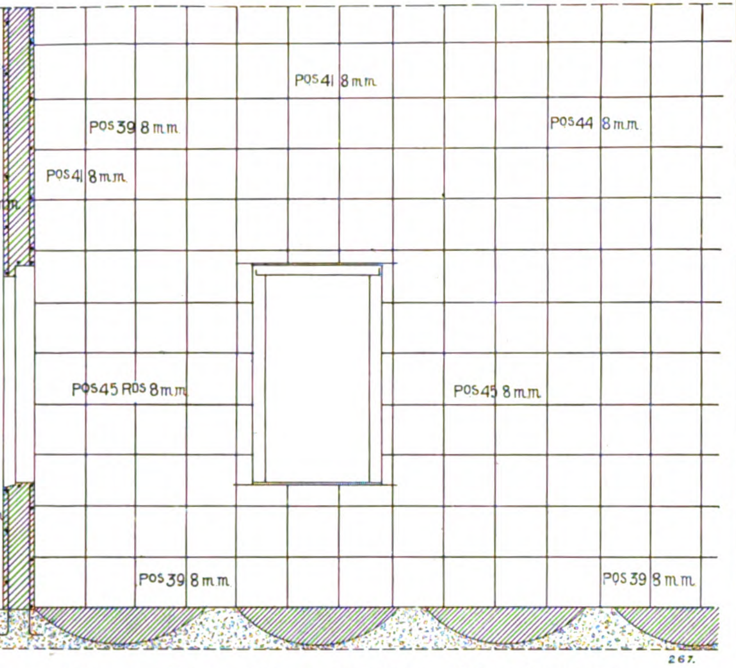


Fig. 9. Elevation of External Wall Interior.

The whole of the machinery for the working of the silo is set up in the building adjoining one end of the silo. This necessitated making a large number of openings in the decking. The design shows how severely the adaptability of the reinforced concrete construction is tried, the conditions being fulfilled without injury to the solidity. This annexe, with a floor load calculated at 1,000 kg. per square metre, was constructed as a reinforced concrete frame, brick walls, one brick thick being added. The same applies to the loft above the whole row of bins.

It should again be pointed out that this construction has succeeded excellently in the face of most unfavourable conditions of loading. Thus the soil, which was so soft as to yield to the foot, has been enabled, by the use of the large sill, to carry a load of about 1·60 kg. per square cm.=16,000 kg. per square metre, without measurable settling.

The photograph shows the completed building.

Since the great height through which the grain has to fall gives rise to high, although not exactly determined pressures, considerable reinforcement was necessary, as may be seen from the detail drawings. It was nevertheless possible to economise space and to use thin walls. The principal reinforcement of the wall panels is vertical, whilst the horizontal 6 mm. rods only take up minor stresses. The panels are carried by the

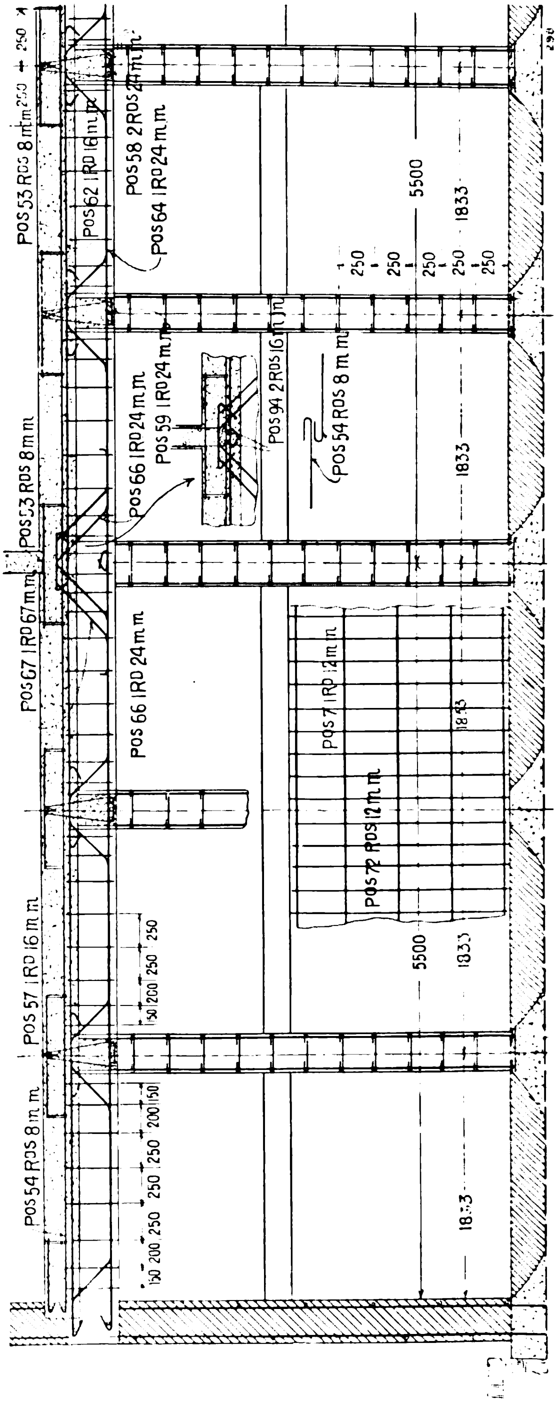


FIG. 10.

horizontal beams, the principal reinforcement of which is horizontal and is kept in place by vertical stirrups. The columns beneath the bins have only vertical pressures to resist, and do not therefore differ from the ordinary type. The reinforcement of the sole is obvious from the diagrams and does not need further description.

In considering the time occupied in construction, it must be borne in mind that a lack of competent and willing workmen had to be contended with, but nevertheless, only 8½ months were required in the actual construction of the building. The total cost amounted to Mk. 101,000 (£5,500).

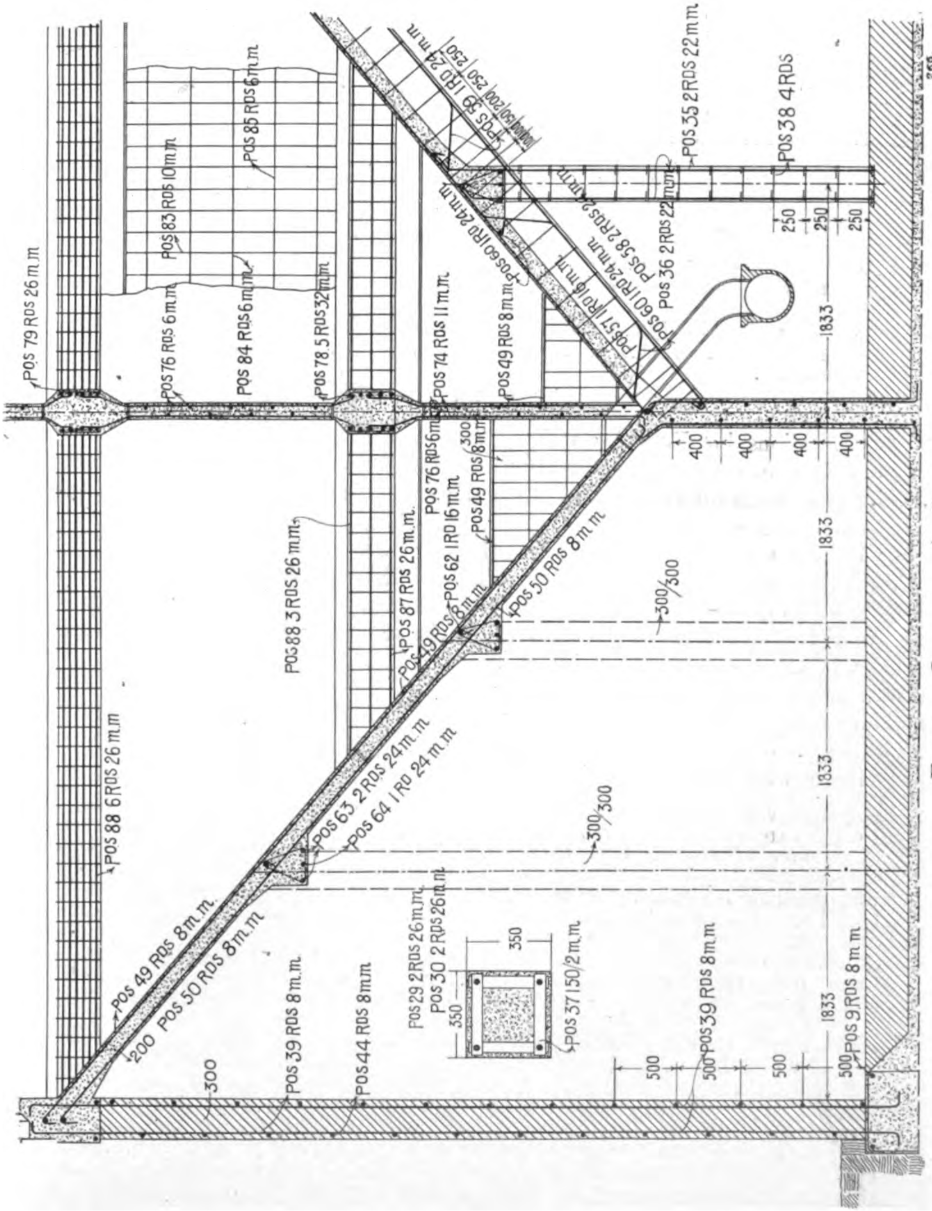
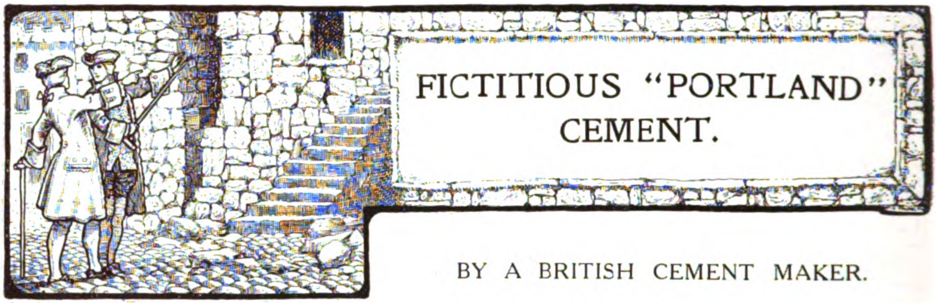


FIG. 11. LONGITUDINAL SECTION.



FICTITIOUS "PORTLAND" CEMENT.

BY A BRITISH CEMENT MAKER.

We have from time to time called attention to the danger of using fictitious "Portland" cement, which is primarily of Belgian origin, as far as Great Britain is concerned. We are collecting data as to instances where the collapse of buildings or other accidents can be proved to be directly due to this unreliable material, but a considerable time must yet elapse before we can issue our first list.

We have presented the professional point of view as to the danger of purchasing Portland Cement under false labels, but below we now also put forward the views of a well-known British manufacturer who prefers to remain anonymous.

This article we hold to be a most timely one, seeing the Consular Report just issued.—ED.

THE annual Consular Report on Belgian trade, issued by the Foreign Office about a year ago, contained some very outspoken comments by Sir Cecil Hertslet (H.B.M. Consul-General at Antwerp), on the methods pursued by certain Belgian cement manufacturers, who employ the English language exclusively on their cask labels with the sole object of deceiving the consumer, and leading him to imagine that what he is buying is a genuinely British product and therefore of high quality. Annoying and injurious as is this practice to British manufacturers, it nevertheless brings with it the consolation that, despite the criticisms of some other British Consuls, who think it smart to describe their fellow-countrymen as both ignorant of and unwilling to study the needs and preferences of the foreign consumer, Belgian manufacturers still find it an advantage to make the consumer believe that what he is buying is of British origin. In his latest report, just issued, Sir Cecil returns to the charge with the following observations:—

> In my last report on the trade of Belgium, published in September, 1905, I called attention to the practice followed by almost all Belgian cement manufacturers of marking or labelling their goods with trade marks described in English, with the obvious intention of encouraging the supposition of buyers abroad that the cement they purchase is either of British manufacture or has some connection with the United Kingdom. For instance, in the case of South Africa, it is well known that a considerable quantity of Belgian cement is employed in that country, yet the totals of the exports of cement from Belgium are but comparatively small annually—1903, 22,907 tons; 1904, 14,148 tons; 1905, 10,246 tons. It would, therefore, appear to be the fact (whether or not it is so, manufacturers in the United Kingdom are better able to judge) that a great deal of Belgian manufactured Portland cement exported hence to the United Kingdom, bearing trade descriptions in the English language, is re-exported from the United Kingdom to other countries and British colonies, the reason being that the merchants or agents buying the cement can obtain it at a cheaper rate in Belgium than in the United Kingdom. It is unnecessary for me to recapitulate here the reasons why cement and other articles can be manufactured more cheaply in Belgium than elsewhere, as I have already given them on more than one occasion; it is sufficient for the purpose to state (and the fact is a known one) that cement is manufactured more cheaply in Belgium than it can profitably be in the United Kingdom. Whether the quality of Belgian cement can compare with that of British manufacture is a matter for expert opinion.

> The defence of the Belgian manufacturer for describing some of the cement manufactured in this country as "Portland" cement is that the word "Portland" is only used to describe a particular quality of cement obtained by a certain process, and that the name cannot, therefore, be peculiar to cement of British make. It is not, however, so much the use of the word "Portland" to which exception is taken as the practice of Belgian manufacturers in using the English language on the labels and trade marks placed upon barrels, sacks, etc. As I have mentioned on a previous occasion, in the report above referred to, many labels to be used on barrels of cement for export to South Africa have come under my own notice in connection with the necessary formalities for the registration of trade marks in British colonies. These labels, of which I have seen a large number, consisted without exception, of a device, described as ".......... brand," "best quality," etc., the entire description being in English. The matter was taken up towards the end of 1905 in the United Kingdom, but so far, to my knowledge, no steps have been taken with a view to having the question of English labels used for Belgian cement regulated.

It is gratifying to find one of our Consul-Generals thus anxious to protect our trade and reputation, but it is perhaps only fair to observe that British cement makers do not claim the exclusive right to the use of the word "Portland," that having been the name given to Portland cement by its inventor, Aspdin, because of its resemblance in appearance to Portland stone, but they have a very strong feeling that the term "Portland" ought not to be used to describe an article which is not produced on orthodox lines, in other words, that it ought only to be used to describe genuine *artificial* cement, and that what is technically known as "natural cement" has no right to the same title.

The British cement manufacturer is quite ready to admit the right of the Belgian makers of genuine artificial cement, to describe their cement by the term "Ciment Portland," nor can he reasonably complain if, when sending his product to a country where English is the usual language, the Belgian maker uses a label printed in English, so long as the place of origin is clearly and properly stated upon it. In such cases the consumer need not be deceived, and if he troubles to read the label he must know that what he is buying is not of British manufacture. In such cases, too, he will judge the goods on their own merits, and, if they be neither cheaper nor better than English cements, his native patriotism will probably incline him to favour his own countrymen in preference to the foreigner.

It would be absurd to deny that genuine artificial Portland cement of good quality has been produced in Belgium for many a long year, but as the cost of production and delivery at Antwerp is practically the same as the cost of production on the Thames and delivery to London (notwithstanding the lower rates of wages prevalent in Belgium), there has been no inducement to dealers or users in Great Britain to import this class of material here in any appreciable quantity. It has proved itself a strong competitor in a few foreign markets, but in none of those known to the author of these lines can it be seriously argued that the English labels have deceived the consumer, or that he does not know perfectly well that what he is buying was produced in Belgium. Against this competition, however, the British maker must be, and is in fact, prepared to hold his own by the only permanently reliable methods known to commerce, *i.e.*, by producing a cement of the highest possible quality and selling it at a competitive price. So long as he can get his goods carried to the point of consumption as cheaply as the Belgian maker can, the British maker will not actually stand in need of preferential tariffs to protect his trade, though he naturally welcomes them when offered.

But the case is different when we come to consider the use of English labels and trade marks upon the bulk of the material which comes into Great Britain from Belgium, under the title of "Best Portland Cement," and one is led to ask whether the time has not arrived when the Legislature should step in, as it did years ago in the matter of margarine, and say once for all in legal form that an article which is *not* genuine artificial Portland cement—which does not go through the same processes of manufacture, and which is perfectly well-known in all trade circles under a different and distinctive name, as well in its own country as here—should be honestly sold for what it is, and no longer be palmed off on an ignorant public under a name to which it has no right, to the injury alike of the buyer, of the honest trader, and not infrequently also of the good repute of the genuine article whose name it has usurped.

What then is the difference between the genuine article and the imitation? The want of any formal definition for use in Great Britain was met by a resolution of the London Chamber of Commerce in 1898, when it was laid down:—

> That Portland Cement be defined as a mixture of two or more suitable materials intimately and artificially mixed in the requisite proportions, and afterwards properly calcined and ground, to which nothing has been added during or after calcination, except that an addition not exceeding 2 per cent. of gypsum is permissible for the purpose of regulating the setting.

As indicated in this definition, genuine "Portland Cement" is prepared by the mixture of at least two separate raw materials (in the British Standard Specification these are properly described as "calcareous and argillaceous"), and as their chemical composition always varies more or less, it is necessary to vary the proportions of each of them from day to day and hour to hour in order to obtain a correct and uniform composition in the cement itself. Without uniformity in the raw mixture it is impossible to produce satisfactory cement, and it is easy to explain this by reference to one point only, viz., the proportion of calcium carbonate as it affects the temperature necessary for perfect calcination. The higher it is, the greater must be the temperature to produce complete chemical fusion. If, therefore, a raw mixture of varying proportions be subjected to a uniform temperature during calcination, that which is under-limed will be over-burnt and vitreous, whilst that which is over-limed will be under-burnt, with the result, in the latter case, that perfect chemical combination will not be brought about, and there will be free or uncombined lime, which, as everyone knows, is what causes cement to "blow."

The reader will deduce from these facts that in the production of genuine Portland cement there is always a mixture of the raw materials, and the resulting mixture must be uniform in its chemical composition; but something more than these is also required, viz., that the chemical components—the calcium carbonate of the chalk, limestone or marl, and the silica and alumina in the clay or shale—shall not merely be in correct proportions when calculated on large volumes, but shall also have been reduced to such an extreme degree of fineness, and so perfectly and uniformly intermixed that, when calcined, the chemical fusion shall be uniform and complete. To ensure this result it is necessary to combine skilled chemical control with an adequate expenditure of mechanical power. Both of these involve considerable outlay, and in proportion to this outlay success is, or should be, attained. It goes without saying that the quality of the finished product depends also on the care and perfection with which the subsequent stages of calcination and grinding to powder are carried out, but the first element of success lies in the perfection of the mixing process which is the distinguishing characteristic of all genuine Portland cement.

And now, what is this "imitation," to which the author of this paper refuses all title to the name of "Portland Cement"? It is known to the trade everywhere as "Natural Cement." In Belgium and France it is called "Ciment Naturel." In the United States, where also large quantities are produced, it is honestly sold as such under a distinctive title, and nobody attempts to christen it "Portland Cement." As the "Rosendale" cements of the United States are never imported into Great Britain it is unnecessary to treat of them here, but as almost the whole of the material imported into the United Kingdom from Belgium, and sold as "Portland Cement" is nothing more than 'Ciment Naturel," it is not only needful that its true character should be known, but it is high time that those who deal in it should be compelled to do so in a straightforward manner and forced to sell it under a distinctive title, so that the purchaser may know what he is getting. Legislation of this character would not prevent its importation or use. The consumer who is content with hydraulic lime would still be able to get the Belgian "Natural Cement" whenever he wanted it, and he would get it, moreover, at its natural price, instead of paying, as he now too often does, an artificially inflated price because the dealer is free to sell it under a name which is universally held to represent a different and more expensive article.

But I am anticipating. Let me explain its true nature, so that the basis of this argument may be made clear. In the vicinity of Ghent and Tournai, in Belgium, there exist large mineral deposits in which Dame Nature has conducted the mixture of calcareous and argillaceous materials in a rough and ready manner. These exist for the most part in the form of rock, but the strata are exceedingly variable in their chemical composition both vertically and horizontally. The percentage of rock of even fairly accurate composition is very small in any of the quarries; of the remainder, some contains an excess of carbonate of lime, and when calcined, yields an article of dangerously expansive character, but the greater portion is deficient in carbonate of lime, and therefore yields a cement of low specific gravity and poor tensile strength. To separate the small proportion of good rock from the remainder would be too costly a process; consequently "the run of the quarry" goes straight into the kiln. There is no analysing, grinding, mixing or drying of the raw material and no scientific control. The rock undergoes nothing more elaborate than what is necessary for the production of ground lime, and, indeed, much of it is sold in Belgium as "Chaux Hydraulique," and not as "Ciment."

Now mark also what must happen in the process of calcination of these variable qualities of rock. It is impossible for the makers to vary the temperature to suit the varying proportions of calcium carbonate. They must just strike a sort of average when adjusting their proportions of fuel, with the inevitable result that the low-limed rock is over-burnt, and the high-limed rock is under-burnt, and the subsequent mixture of these different clinkers during the grinding process is impotent to correct these errors. This is clearly shown by the Le Chatelier test and by the boiling test, which are usually fatal to "Natural Cement." By way of illustrating this thesis, the writer may mention a case which came under his own notice. A sample of cement, which had been supplied to one of the chief municipalities of the United Kingdom as "Best Portland Cement," but which was in reality a Belgian "Natural Cement," yielded no less than 37½ millimetres expansion under the Le Chatelier test, whereas the permissible limit for Portland cement, as laid down in the British Standard Specification, is 12 millimetres. The other tests for soundness were equally unsatisfactory, the pats immersed in the Deval bath (180 deg. F.) and in boiling water all buckling and cracking, revealing the presence of free uncombined lime.

A very ready means of detecting the true character of this "Natural Cement" lies in the specific gravity test, for here again it differs notably from the genuine article. The British Standard Specification for Portland cement requires a minimum specific gravity of 3·15 when freshly ground, or 3·10 when aged. Natural cements rarely if ever, reach a specific gravity of 3, and in Belgium itself the Government is most insistent on this specific gravity test on purpose to protect itself against the foisting of "Natural Cement" upon public works for which "Portland Cement" is specified. If this be the attitude of the Belgian Government authorities towards this product of their own country, ought not engineers and architects in Great Britain to be at least equally careful to exclude "Natural Cement" from all works under their control for which they desire "Portland Cement" to be employed? They can do this in their specifications by using the word "artificial," in addition to the words Portland cement, until such time as Parliament finds time and inclination to protect them and the public against this particular form of deception, and compels "Natural Cement" to be sold as such, and not as "Portland."

To revert, in conclusion, to Sir Cecil Hertslet's remarks, it is undoubtedly a hardship that this inferior product, which, as I have tried to show, is not fairly described as "Portland Cement" at all, should be shipped to foreign countries under English labels, with the double result that the good repute of genuine "Portland Cement" is often injured and the fair name of British manufacturers and British goods aspersed. Cannot our Government do something to assist British Portland cement manufacturers in this matter?

Meanwhile, it is, of course, satisfactory to note that the import of this inferior material into the United Kingdom has been steadily diminishing during the present year. Sir Cecil Hertslet's report, in alluding to the Belgian export statistics says:—

> The salient point of the returns down to June 30th, 1906, is that the exports to the United Kingdom fell off very considerably, declining from 113,067 tons in 1905 to 79,949 tons in 1906. The United Kingdom, however, still remains the principal market for Belgian cement, though not to such an overwhelming extent as heretofore. The colonies also show a certain falling off, though only of minor importance.

This falling off (which, by the way, has also continued during the three months following June) may in part be attributed to the reduced prices of genuine English artificial cement, but is probably due in even larger degree to failures in work done with the Belgian natural cement, which has led the British user to discover—when too late—the real nature of the material which had been palmed off on him as "Portland Cement," and has put him on his guard against it.

MEMORANDA.

Memoranda and News Items are presented under this heading, with occasional editorial comment. Authentic news will be welcome.—ED.

Reinforced Concrete at the Post Office.—It is with considerable interest and pleasure that we announce that reinforced concrete is to be probably extensively applied in the construction of the General Post Office Extension on the Christ's Hospital site, Sir Henry Tanner, of H.M. Office of Works, acting as architect.

* * *

Reinforced Concrete Water Towers.—Among the notable reinforced concrete water towers that are now about to be erected, we observe that the North-Eastern Railway Company are having two designed by Mr. W. J. Cudworth, one of the chief engineers of the Company. These tanks will be used for the Ulleskelf water scheme, the one being designed to hold 60,000 gallons and the other 20,000 gallons of water. The Yorkshire Hennebique Contracting Co., of Leeds, are undertaking the erection.

* * *

Portland Cement in Collieries.—It is now extensively used in the Pennsylvania collieries, according to Mr. Edward McGrew, as a lining for pipes and pump chambers, which contain the sulphur-impregnated waters from such mines. Wood lining is sometimes used for lining in the pumps when they are of the plunger type. It has become customary now, he states, to use boreholes to pump through. A hole is drilled, and an ordinary wrought-iron casting put in and surrounded with cement grout. After the casing is eaten out by the action of the water the cement lining protects the hole indefinitely.

See *Scientific American* of May 12th, 1906, for fully illustrated description of cement used in armoured concrete for various purposes.

We also observe that German mining engineers are commencing to use reinforced concrete linings in the place of the wooden linings for collieries, and a new shaft for the Koenig Colliery, which will have a depth of 470 ft., has just been started in reinforced concrete.

* * *

British Portland Cement and the Valparaiso Earthquake.—But little reliable technical information has as yet reached us as to the effect of the earthquake at Valparaiso upon concrete work or upon brick buildings built in cement mortar. One item of some interest we would, however, mention among those received, namely, a communication from Messrs. Williamson, Balfour and Co., of Valparaiso, that Portland cement concrete foundations of buildings executed by them entirely in "White Bros." Portland cement have stood the earthquake shocks absolutely without a crack, and that where brickwork built in " White Bros." cement was employed they can trace no instance where the brickwork gave in the cement joints, the bricks themselves breaking or giving way. This is certainly pleasant reading for the British cement makers generally and the owners of " White Bros." brand in particular.

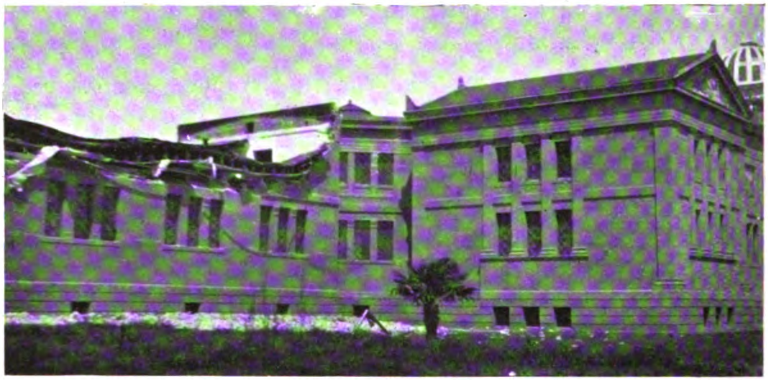
* * *

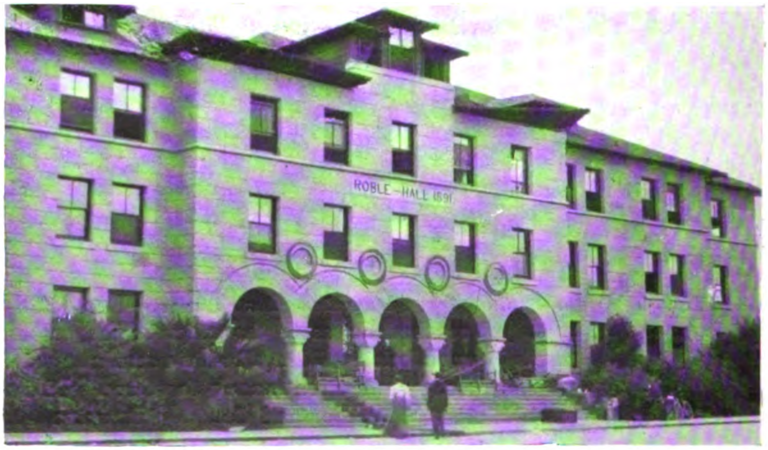
The Stanford University Concrete Buildings, San Francisco, U.S.A.—These buildings have been frequently referred to as remarkable examples of the efficiency of concrete construction to resist earthquake shock, even if there be no steel reinforcement.

The efficiency is perhaps best realised by the presentation of views of two of these buildings, taken directly after the earthquake, and we do this by the courtesy of the *Engineering News* of U.S.A. The photographs speak for themselves, and it should be remembered that the buildings in question were subjected to a sequence of very severe shocks.

* * *

The Newhaven Harbour and Concrete Piles Generally.—The Newhaven Harbour Commissioners report that the timber piling of the West Pier has become defective owing to the action of the "Toledo," and these will shortly be replaced by reinforced concrete piles. The action of the "Toledo" is scarcely fully appreciated as yet by harbour authorities, and the economy of the reinforced concrete pile not as yet fully realised. Nor does it appear to have been fully realised hitherto that there is no monopoly in reinforced concrete piling, and that there are various ways of constructing them without in any way assimilating the French type that





THE STANFORD UNIVERSITY, SAN FRANCISCO, U.S.A.
The Museum and "Roble Hall" buildings, being monolithic buildings, without steel in walls.
Views taken directly after earthquake.

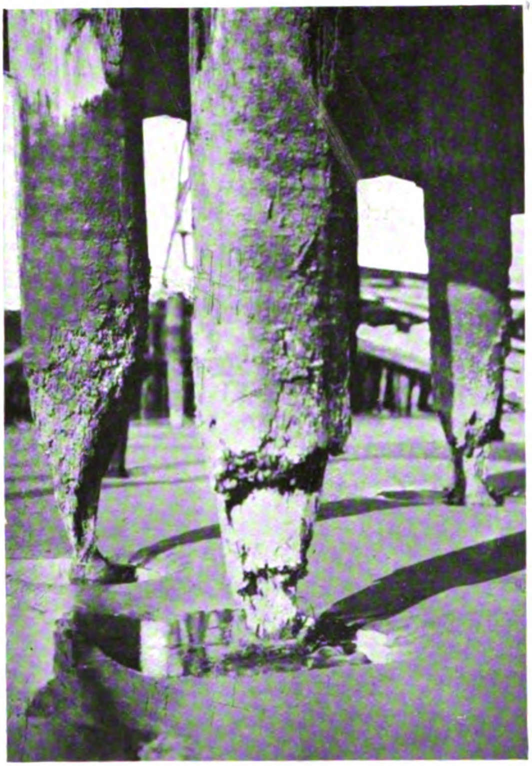
has been recently before the courts. We refer readers to the article by Mr. A. T. Walmisley, M.Inst.C.E., in our first issue, and to our report on the patent action in our fourth issue. However, to give some idea of the ravages of the "Toledo" on timber piles we present some illustrations courteously put at our disposal by *The Cement Age* of U.S.A.

* * *

The Junior Institution of Engineers.—A party of members of this Institution, approaching 100 in number, availed themselves of the invitation given by the Associated Portland Cement Manufacturers (1900), Ltd., to visit their Northfleet Works on Saturday afternoon, September 22nd. Divided into small groups, they were shown round by Mr. H. K. G. Bamber, F.C.S., one of the managing directors, and members of the staff.

* * *

Trade Announcements. — We understand that the Trussed Concrete Steel Company (Kahn System) of Caxton House, Westminster, S.W., who have only been established in this country a few months, are providing steel for various important works; already 58 contracts have been given the company for Kahn bars. The work for which these have been, or are destined to be used, include: Coal bunkers for a cement works, a factory at Carlisle, structural members of the Hammersmith Baths, quay for the Southampton Harbour Board, Bridges at Lilburn and Lucker for the Northampton County Council, two viaduct bridge constructions, an aqueduct ditto for the Blackburn Corporation, columns and beams at Messrs. Whitbread's brewery, floors at the City Chamber, Leeds, etc.


THE EFFECT OF THE "TOLEDO" ON TIMBER PILES.

The Bridgeport Theatre Company, of Bridgeport, Conn., U.S.A., are now manufacturing concrete blocks for the erection of a large and handsome theatre. It is estimated that 50,000 blocks at least will be required, together with 1,500 ft. of water table, sills, etc. It is stated in the American press that this is to be the first of a chain of theatres to be erected of concrete blocks throughout the East. Hercules machines made by the Century Cement Machine Company, Rochester, New York, U.S.A., are being used exclusively, and the stone provided is said to be exceptionally fine.

TESTS WITH CONCRETE

AT HOME AND ABROAD.

We consider that the absence of reliable information as to the various tests carried out with concrete both at home and abroad has frequently led to misconceptions as to the qualities of this material, and we shall thus for the present accord considerable space to the presentation of authentic data that may be of service to those employing concrete in its various forms. The tests which will particularly call for our attention are those relating to strength, fire-resistance, and waterproofing.—ED.

TENSILE AND BENDING TESTS OF REINFORCED CONCRETE.

By PROF. F. SCHULE.

A NEW series of the Reports of the Swiss Federal Station for the Testing of Materials at Zürich opens with this handsome quarto of 142 pages, with seven plates and seventy figures. Professor Schüle has brought all the resources of the testing laboratory of the Zürich Technical School to bear on the examination of reinforced concrete, and the result is a most valuable and exhaustive report in which certain conditions, hitherto almost neglected, have been studied with special care. The detailed account of the investigation, which demands careful study, does not lend itself well to the preparation of a summary, and only certain points can be touched on here.

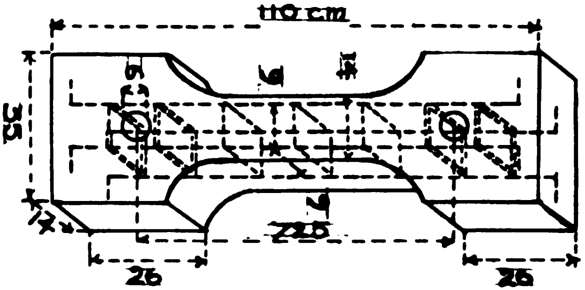


FIG. 1.

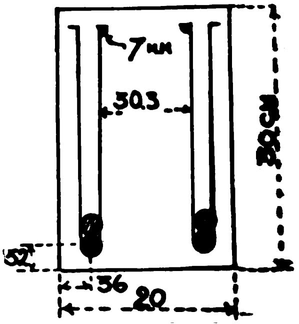


FIG. 2.

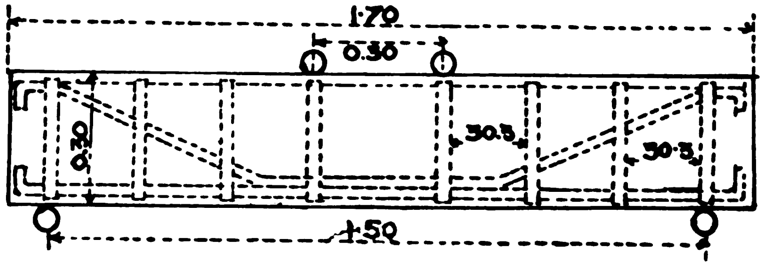
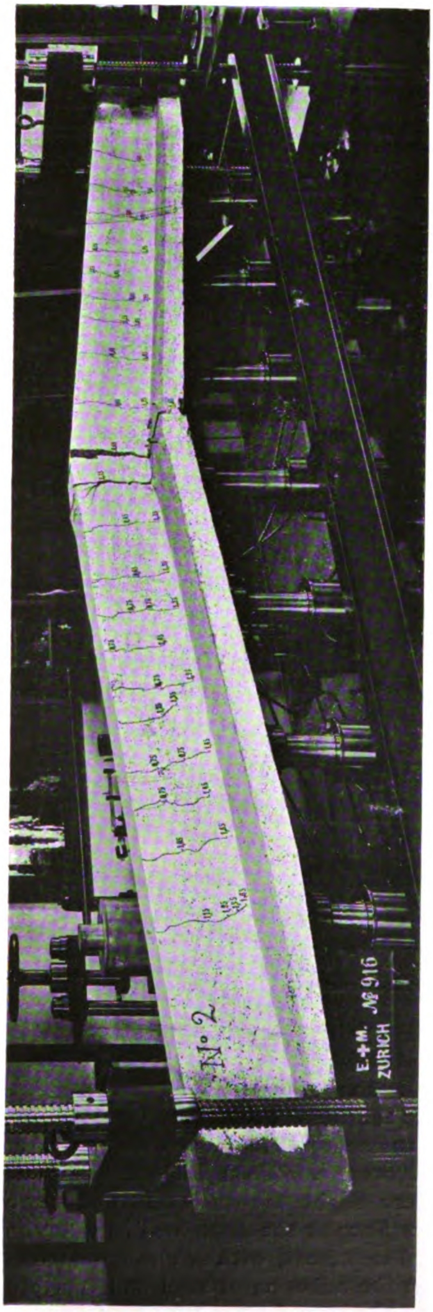
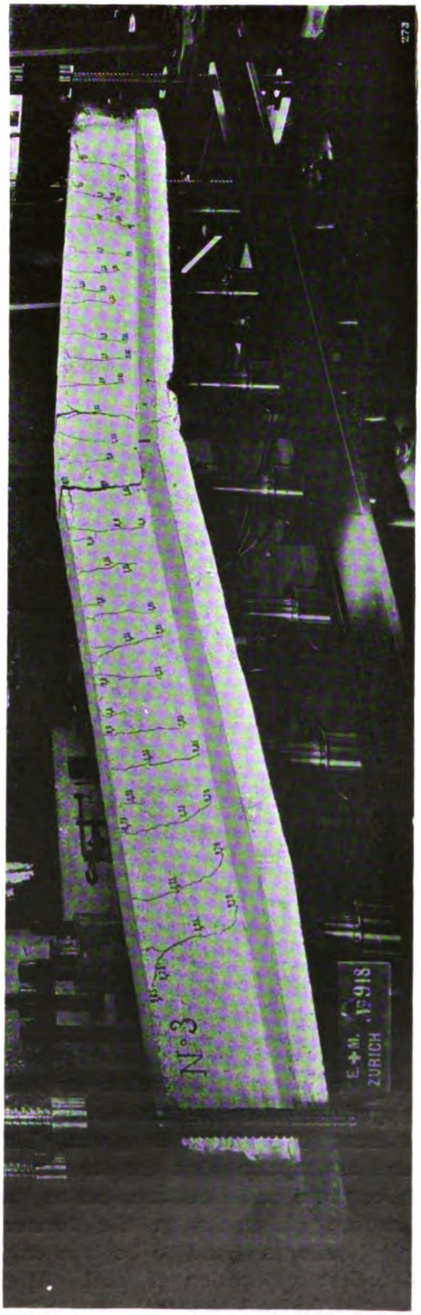


FIG. 3.

Professor Schüle has directed special attention to the question of the amount of permanent deformation of a reinforced concrete beam or other structure remaining after removal of the load. The usual formulæ for the calculation of such structures are based on the assumption



Beam No. 2 (4 Bars of 15 mm.). Age, 67 weeks.



Beam No. 3 (4 Bars of 22 mm.). Age, 56 weeks.

that the deformations produced by loading remain within the elastic limits, and the author's proof that this is not the case, even for moderate loads, will have an important bearing on the choice of formulæ.

The first group of experiments deals with tests in pure tension. The test-pieces were of the form shown in *Fig.* 1, the test piece being held by pins passed through the holes shown, and a detailed description of the micrometric methods employed in measuring the elastic and permanent elongations is given. The general assumption that the stresses in both concrete and steel are, before the appearance of cracks in the former, purely tensile, is found to be true only of the first application of load. After removal of the load, the steel remains in a state of tension, producing a compressive stress in the concrete. The results obtained in making a test of a concrete structure, therefore, depend on whether the structure has been previously loaded or not. When cracks have appeared, a greater proportion of the stress is taken by the reinforcement, but permanent stresses are still present unless the ends of the reinforcing rods have given way, or the elastic limit of the metal has been reached. No sudden change of stress is, consequenly, noticed at the moment of appearance of cracks in the concrete. When the reinforcement is very slight (0·1 per cent.), fracture takes place at the same load as when no metal is present; with stronger reinforcement the adhesion of steel and concrete is greatly dependent on the richness of the latter. The extensibility of the concrete

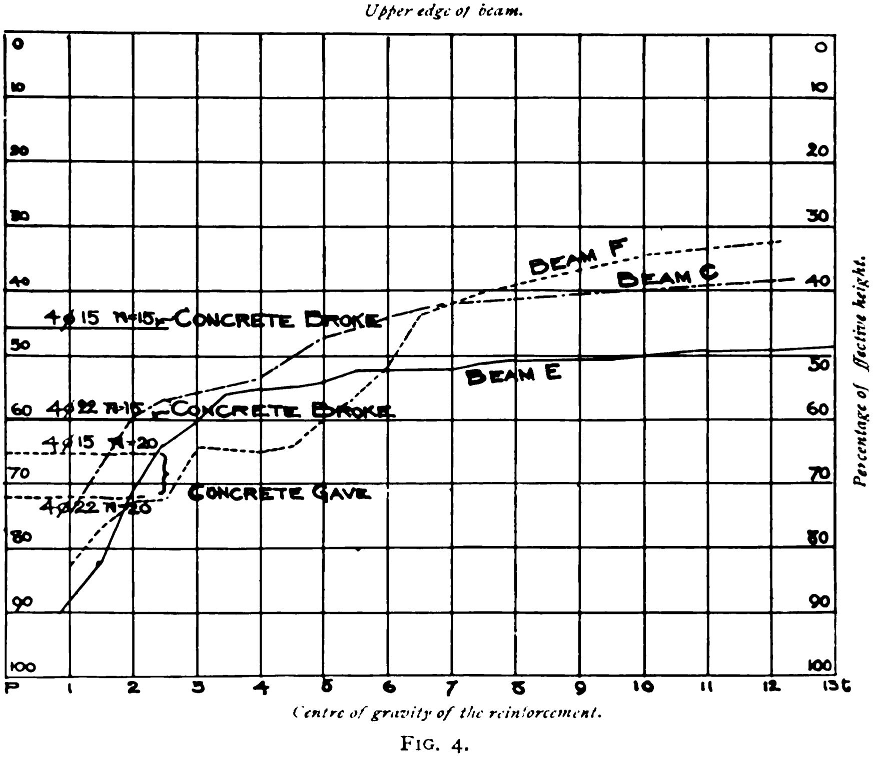
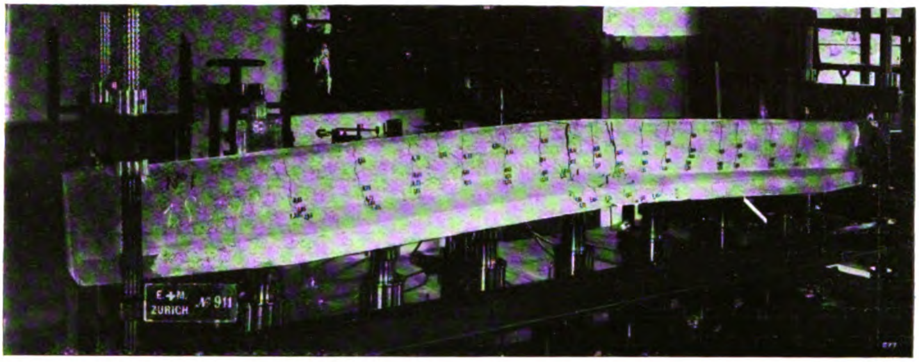
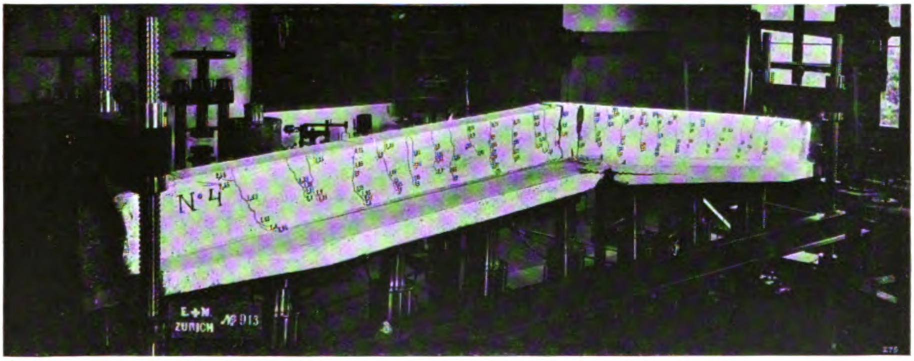


FIG. 4.

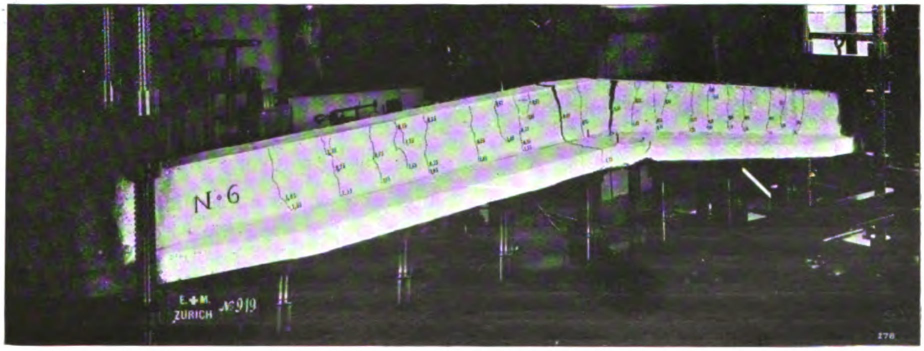
is considerably increased by the presence of the reinforcement.



Beam No. 1 (4 Bars of 15 mm.). Age, 65 weeks.



Beam No. 4 (4 Bars of 22 mm.). Age 53 weeks.



Beam No. 6 (4 Bars of 15 mm.). Age, 55 weeks.

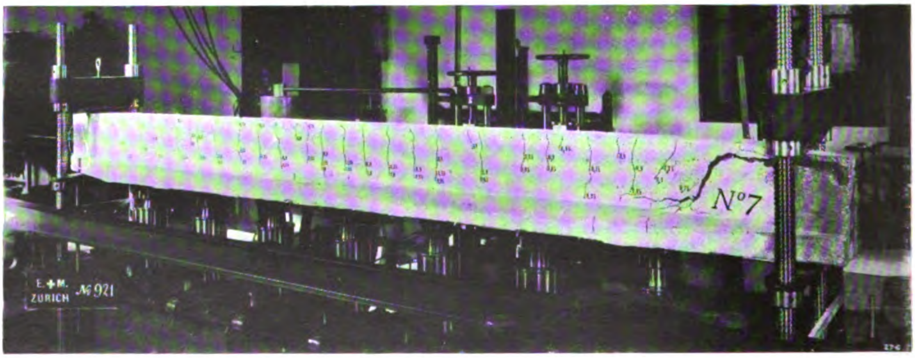
BENDING TESTS.

The second series of experiments was devoted to bending tests on reinforced concrete beams, carried out by means of an Amsler testing press. The form and mode of reinforcement of the beams is seen from *Figs.* 2 and 3, the central load being applied, not at a single point, but by means of two rollers 30 cm. apart. Particulars of four beams are given below:—

BEAMS.	B	E	C	F
4 Reinforcing rods of	22	22	15	15 cm. diam.
Cement per cubic metre of ballast and sand	200	500	200	00 kg.
Age	7	8½	10½	10½ months.
Compressive strength of concrete	245	596	287	637 kg/cm.²
Total load at breaking	30	31·4	17·5	20·9 tons
Bending moment at middle point	900	942	525	627 cm. tons
Maximum compressive stress in concrete	550	748	446	640 kg/cm.²
Ratio to compressive strength, unarmoured	2·25	1·26	1·56	1·00
Maximum tensile stress in steel	2·71	2·71	3·15	3·61 tons/cm.²

Here, as in the tensile tests, the deformation remaining after removal of the load was found to be considerable, amounting, in the steel under tension within the working limits of load, to one-half of the total elongation. The permanent deformation of the beam in the centre by bending may amount under the same conditions to $\frac{1}{4}$–$\frac{1}{3}$ of the total deflection.

The author compares together the Swiss method of calculating such beams ($n=20$), and the German method ($n=15$). All such methods, however, are based on the assumption that a transverse plane section remains plane after deformation. Experiments show that this is not the case, and calculations of the position of the neutral axis based on that assumption result in fixing the neutral axis above its true position. In *Fig.* 4 the height of the neutral axis, expressed as a percentage of the effective height of the beam (from the centre of gravity of the reinforcement to the upper surface of the beam), is plotted against the load. The positions assumed by the two generally adopted formulæ are shown by horizontal lines, and it will be seen that neither method gives correct results within the permissible limits of loading. Even the positions of the neutral axis adopted in plotting these curves are actually somewhat too high.



BEAM NO. 7 (4 BARS OF 22 MM.). AGE, 56 WEEKS.

T-BEAMS WITH DISTRIBUTED LOAD.

For the third series of experiments, a specially designed Amsler press was used, so arranged that equal loads could be applied at seven different points. The form and mode of action of the machine will clearly be seen from the photographs. T-beams were used, all being prepared with the same mixture, of 300 kg. Portland cement per cubic metre. For simplicity in construction, and in order to determine the shearing strength of the concrete more readily, no stirrups were used. Each crack was traced on the surface as it appeared as shown in the photographs. Very concordant results were obtained with beams one year old. Beams only six weeks old gave more variable results, probably owing to stretching taking place without the appearance of cracks.

The author's principal conclusions are:—

The permissible stresses in the steel depend on the elastic limit; when this is 2·7–3·2 tons, and $\sigma_e = 1000–2000$ kg. per square cm., a factor of safety of 2·2–3·2 may be reached, but this may easily fall to 2 or less if the concrete is insufficiently hardened, or too poor in cement, or if the ends of the reinforcing rods are inadequately prevented from slipping. In that case it is not the bending moment of the beam at its middle point, but the shearing force, which determines fracture.

The compressive stresses in the concrete are considerably greater than those determined by the usual methods of calculation. When the elastic limit of the steel has been reached, these compressive stresses increase rapidly as the cracks in the beam widen. It is necessary that the compressive strength of the concrete should be high, but the experiments indicate that this is less on account of the actual increase of strength than in order to prevent dislodgment of the ends of the reinforcing rods.

The permanent deformations after removing the load, when the first cracks have appeared, relieve the stresses in the steel, so long as the elastic limit is not reached; but they produce an increase in the compressive stresses, which has hitherto been overlooked. Repeated loading increases the compressive stresses, and reduces the adhesion.

The usual methods of calculation fail to indicate, even with approximate correctness, the true conditions of stress in the beam. Certain simplifications may safely be introduced. Thus, in plates and beams of rectangular section, the neutral axis may be taken as the middle point of the effective height, and in T-beams at the junction of plate and web. But in

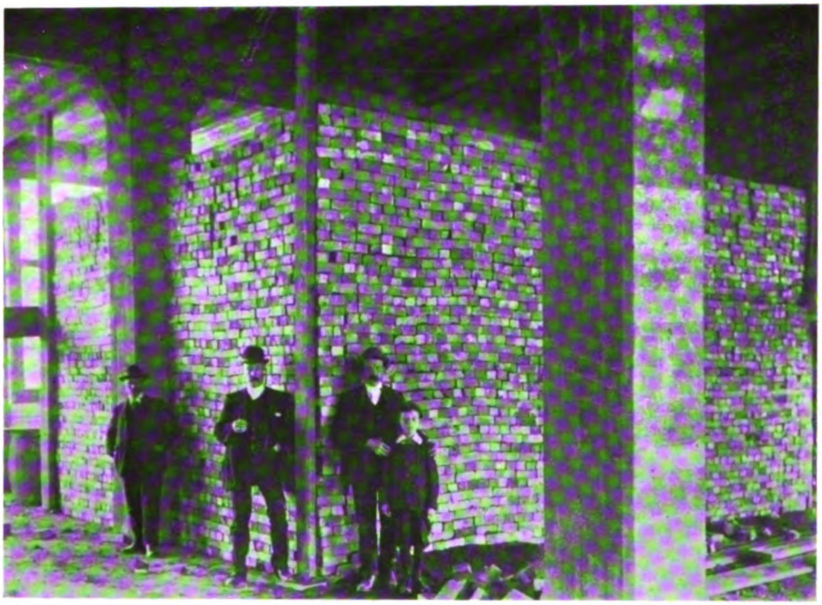


FIG. 1. LOADING TESTS AT YORK.

every such case the conditions of fixing of the ends of the reinforcing rods, and the shearing stresses, should be most carefully studied.

The hardness of the concrete is of the very greatest importance ; centering should be removed as late as possible, and load applied only after several months.

LOADING TESTS IN A REINFORCED CONCRETE FACTORY BUILDING.

A Load of 11¼ cwt. per square foot.

THE new "Melangeur" Block under construction on the Hennebique System at the extensive works of Messrs. Rowntree, York, and referred to in our previous issue as the smaller of the two new factories in hand, is of more than ordinary interest to structural engineers, because it is a good example of cage construction in which the entire framework is built of reinforced concrete, filled in by walls of the same material. It is also remarkable for the extremely heavy loads for which all the floors have been designed. The building includes six storeys in all, and covers an area of 105 ft. by 76 ft. 3 in., the height from foundations to parapet being 93 ft. 6 in.

Results of the Loading Tests.

No. of Amplifier.	Clear Span of Beam.	DEFLECTION.				
		Superload. 7½ cwt. per square foot.		Superload. 11¼ cwt. per square foot.		Aft r Removal of Load.
		inch	Part of span	inch.	Part of span	
1	18'3"	1/16	1/3504	1/4	1/876	nil
2	16'6"	3 64	1/4224	1/8	1/1584	nil
3	17'6"	1/16	1/3360	3/16	1/1120	nil
4	15'6'	nil	nil	1/16	1/2976	nil

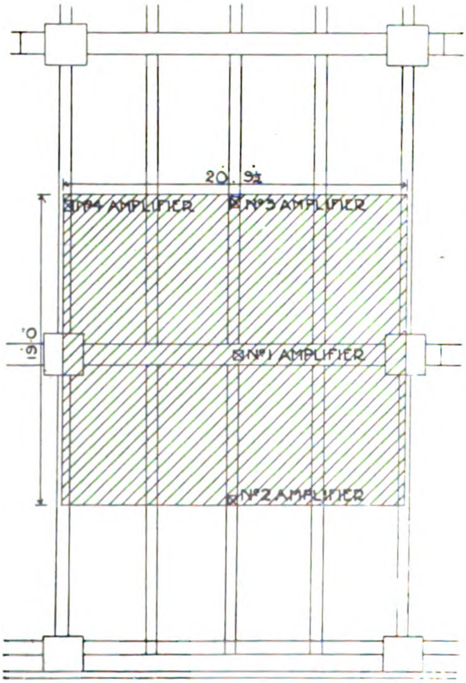


FIG. 2. LOADING TESTS AT YORK.

On September 28th last two tests were made upon a panel of the ground floor which is supported by columns 2ft. 6 in. square, the main beams measuring 15 in. wide by 26 in. deep, and the secondary beams 8 in. wide by 16 in. deep, and the floor slab is 5 in. thick. This floor is destined to carry the heavy mixing machinery employed in the manufacture of chocolate, and was designed for the superload of 7½ cwt. per foot super.

The area tested is shown in *Fig.* 2, where also will be seen the positions of the amplifiers used for the measurement for deflection. In Test No. I. the panel was loaded with nearly 45,000 bricks, weighing 7·4 lb. each, constituting a total weight of about 147½ tons, equal to the specified superload of 7½ cwt. per square foot. In Test No. II. the same floor area was loaded with 66,975 bricks, equal to 11¼ cwt. per foot super, or 50 per cent. more than the specified superload. The results of the Tests are given by Mr. Mouchel in the table given above.

The new factory was designed by Mr. W. H. Brown, Architect to Messrs. Rowntree, and the building has been entrusted to the Yorkshire Hennebique Contracting Company.

NEW WORKS IN CONCRETE

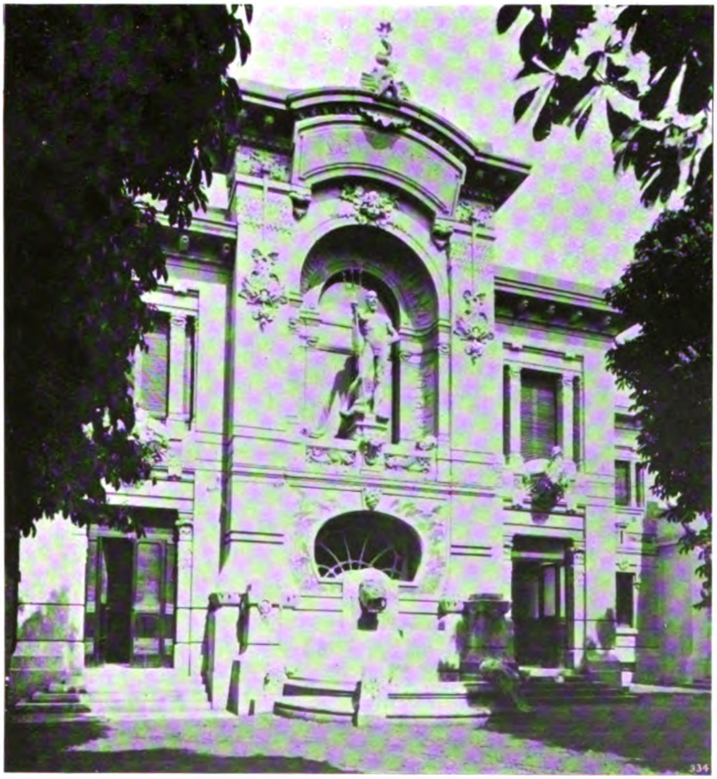
AT HOME AND ABROAD.

Under this heading reliable information will be presented of new works in course of construction or completed, and the examples selected will be from all parts of the world. It is not the intention to describe these works in detail, but rather to indicate their existence and illustrate their primary features, at the most explaining the idea which served as a basis for the design.—ED.

THE REINFORCED CONCRETE AQUARIUM BUILDING AT THE MILAN INTERNATIONAL EXHIBITION.

We have referred to the Aquarium at Milan in an article in our previous issue on the International Exhibition at Milan, and some plans and a section were presented.

We now show the front elevation and a view of the interior, as illustrative of the high artistic merit of this interesting reinforced concrete structure, which is to remain *in situ* after the close of the Exhibition, as a permanent memento of that great undertaking.



Reinforced Concrete Aquarium at Milan.

This reinforced concrete structure may well serve as a model, both of a modern monolithic structure and of architectural design.

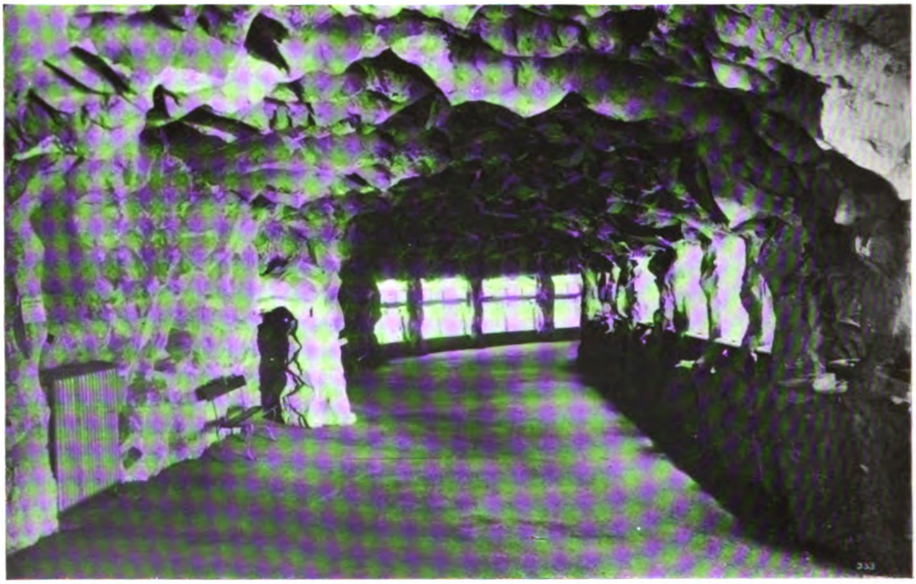
REINFORCED CONCRETE FOUNDATIONS AT RAINHAM.

SOME foundation works of distinctly interesting character have recently been executed in connection with the new premises for Messrs. J. C. and J. Field, Ltd., at Rainham, Essex, in accordance with the Coignet system. The works comprise three principal items: (1) foundations for three Galloway boilers; (2) continuous foundations for the boiler house, 92 ft. 6 in. long by 72. ft 6 in. wide; and (3) continuous foundations for a building 271 ft. long by 41 ft. 6 in. wide.

Owing to the treacherous nature of the ground, which is composed of hard silt to the depth of 3 ft., resting upon a bed of peat about 25 ft. thick, it was impossible to build with safety upon ordinary foundations. The use of timber piling would have been expensive, and might have been prejudicial to the permanence of the superstructure, on account of the probable decay of the timber in consequence of the waterlogged condition of the soil. Having considered the problem in its various aspects, the architects decided to employ continuous foundation slabs of armoured concrete, by which the loads are distributed over so large an area as to keep the unit pressure within the safe bearing power of the ground.

Fig. 1 is a plan of the boiler house in which the foundations for the three boilers are shown at the top right-hand corner. The weight of the boilers is spread over an area of about 40 ft. square, thus reducing the load to 3 cwt. per square foot (see *Fig.* 2). Every possible care was taken to avoid disturbance of the upper stratum of silt. A layer of broken brick a few inches deep was spread over the surface of the ground, and when this had been well levelled, a bed of concrete, 5 in. thick, was deposited, and reinforced by a framework of bars in accordance with the arrangement shown in *Figs.* 3 and 4, the former being a section through the line CD and the latter a part section through EF.

Upon the general foundation slab, six parallel armoured concrete beams were built, as represented in the above-mentioned drawings, to support the fireclay seating blocks for the boilers. It should be observed that, owing to the great rigidity and elastic strength of the armoured construction, it was only necessary to make the slab a few inches thick. If plain concrete had been



REINFORCED CONCRETE AQUARIUM, MILAN.

employed a thickness of several feet would have been demanded, and even then cracks would certainly have appeared, and the weight to be spread over the surface of the ground would have been so much increased as to render the employment of the material impracticable.

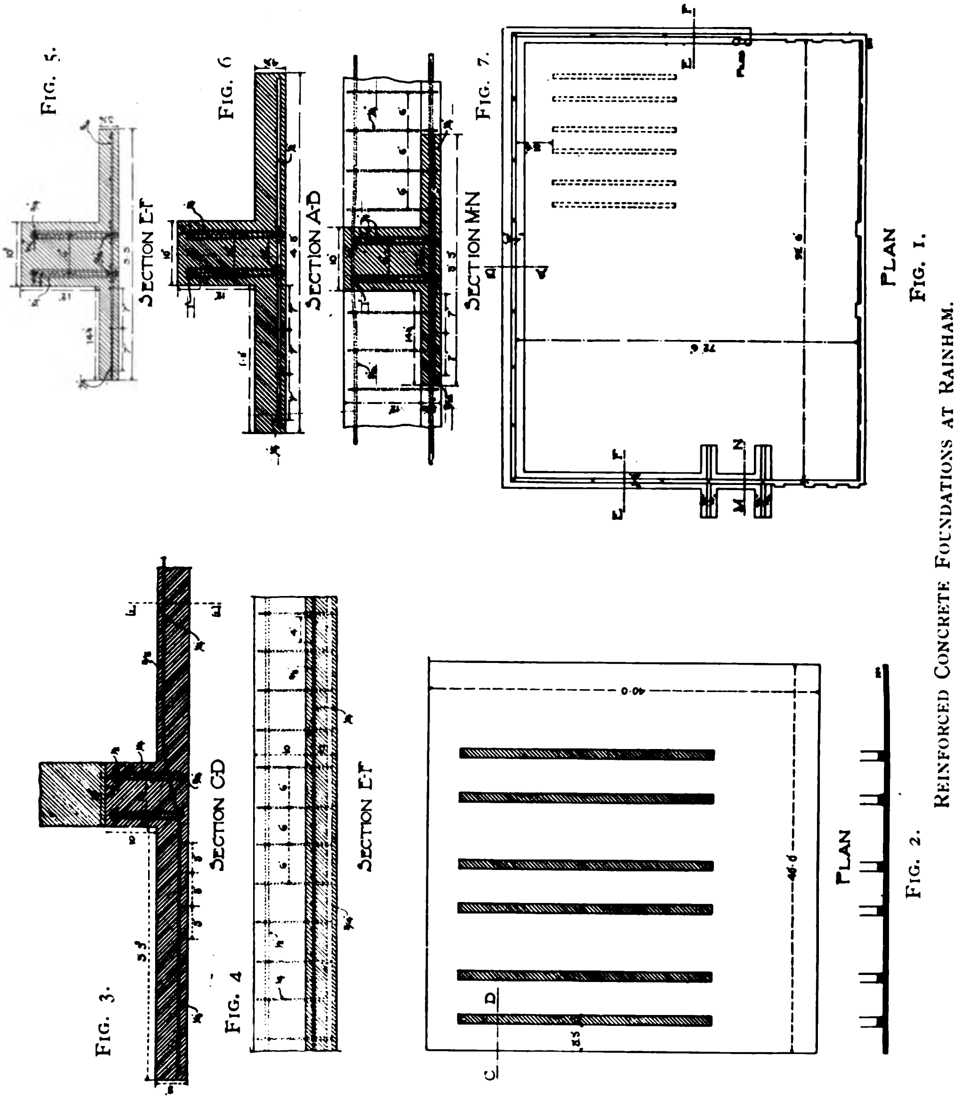


FIG. 5. FIG. 6. FIG. 7. FIG. 1. FIG. 3. FIG. 4. FIG. 2.

REINFORCED CONCRETE FOUNDATIONS AT RAINHAM.

The general nature of the foundations for the boiler house itself will be gathered by reference to *Fig.* 1. In this case the armoured concrete foundation extends around three walls of the building, and consists of footings 4 ft. 8 in. wide, by 3 in. thick along two walls and 4¾ in. thick along the third wall, distributing the weight of the building at the rate of 3 cwt. per square foot over the surface of the ground. Upon this footing a continuous beam 10 in. wide by 12 in. deep was formed, for the purpose of supporting the brick walls of the boiler house, in which it was originally proposed that steel stanchions should be built for the purpose of supporting the roof principals, and bolted at the foot to the armoured concrete beam.

FIG. 10

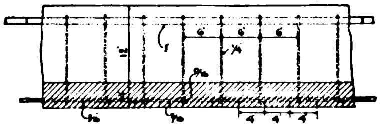
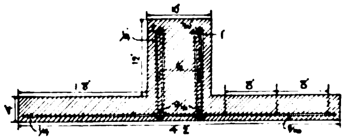


FIG. 9.



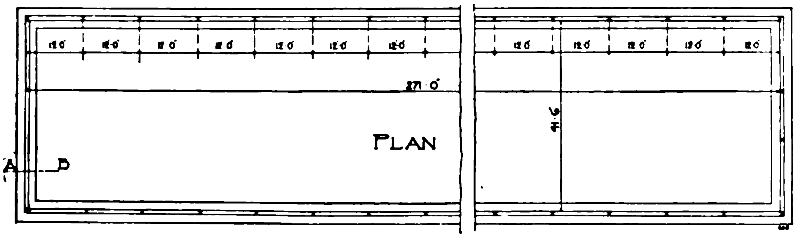
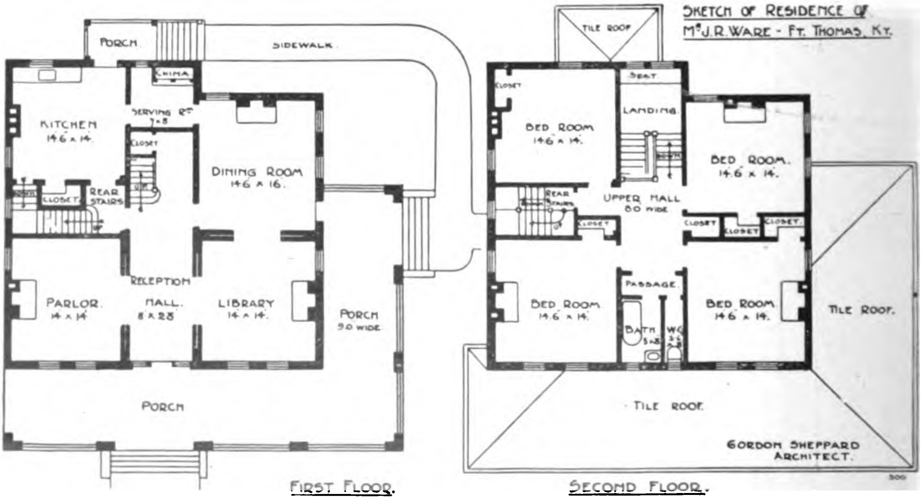


FIG. 8. REINFORCED CONCRETE FOUNDATIONS AT RAINHAM.

At one place where the weight transmitted amounts to nearly 18 tons, the foundation beam has been supplemented by two transverse projections (see MN, *Fig.* 1), and at the opposite side of the building, where the load reaches nearly 36 tons, two piles have been driven.



CONCRETE BLOCK RESIDENCE IN THE UNITED STATES.

Details of the armoured concrete construction will be found in *Figs.* 5 to 7, which are sections through the lines EF, AB, and MN, indicated on the plan (*Fig.* 1).

Fig. 8 is a plan of the shed, 271 ft. long by 41 ft. 6 in. wide, for which the foundations were of generally similar character to those of the boiler house, except that the slab is in the form of a hollow rectangle beneath all four walls of the building. As shown in *Figs.* 9 and 10, the slab is 4 in. thick, and upon it is moulded a continuous beam 10 in. wide by 12 in. deep, the details of the reinforcement being as represented in these two sections.

Since the original plans were prepared we understand that the architects have decided to replace the steel stanchions by armoured concrete columns and lintels resting directly upon the foundation beams of the buildings. As these members will be built monolithic with the foundations, the framework will be far more rigid, and at the same time less expensive than the hybrid construction at first proposed.

In addition to the foundations mentioned in this article, the new premises contain foundations for fuel economisers and the boiler chimney and a set of coal bunkers entirely constructed in armoured concrete.

The architects for the work are Messrs.

CONCRETE BLOCK RESIDENCE IN THE UNITED STATES.

Scott, Hanson and Fraser, of Basinghall Street, E.C., and the contractors are Messrs. W. King and Sons, of London.

It is stated that the armoured concrete work was carried out altogether by unskilled labour, under the superintendence of a clerk of works and contractor's foreman, neither of whom had any previous experience of the material. We presume, however, that all necessary supervision was also exercised by the representatives of the patentees, for it is well known that the execution of work in reinforced concrete is an operation demanding above all things expert superintendence, and the most careful attention to various details connected with the preparation and deposition of the concrete and the disposition of the reinforcement.

CONCRETE BLOCK RESIDENCE IN THE UNITED STATES.

The rapid advances made in concrete block making throughout the United States is most remarkable, and the application of the concrete block is not only to be found in industrial buildings but in villa residences.

An example of such a concrete block residence is here presented, and we understand that plain buildings of this type show considerable economic advantages.

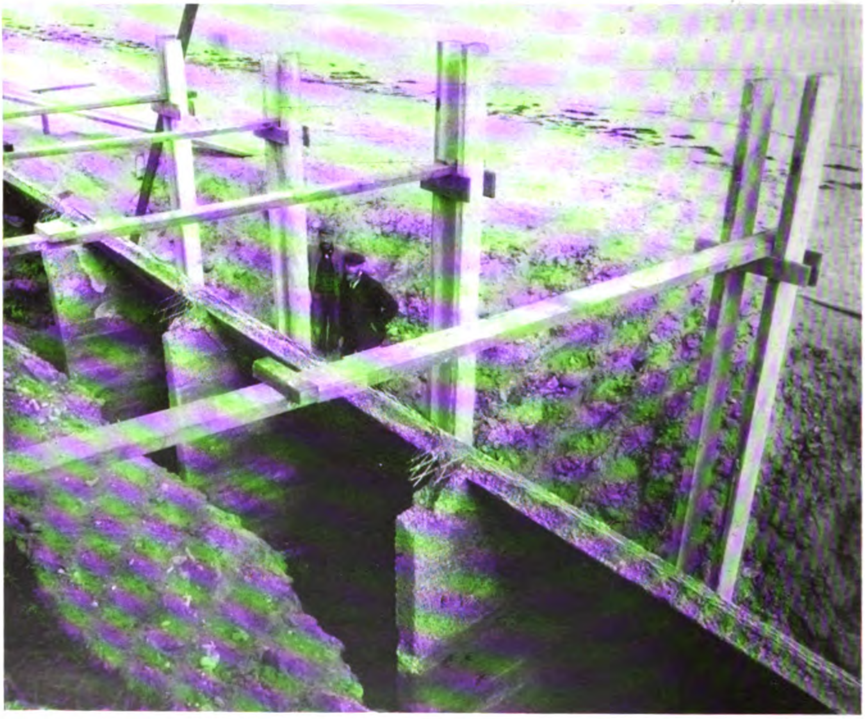
The architect is Mr. Gordon Sheppard.

SEA DEFENCE WORKS NEAR WEST HARTLEPOOL.

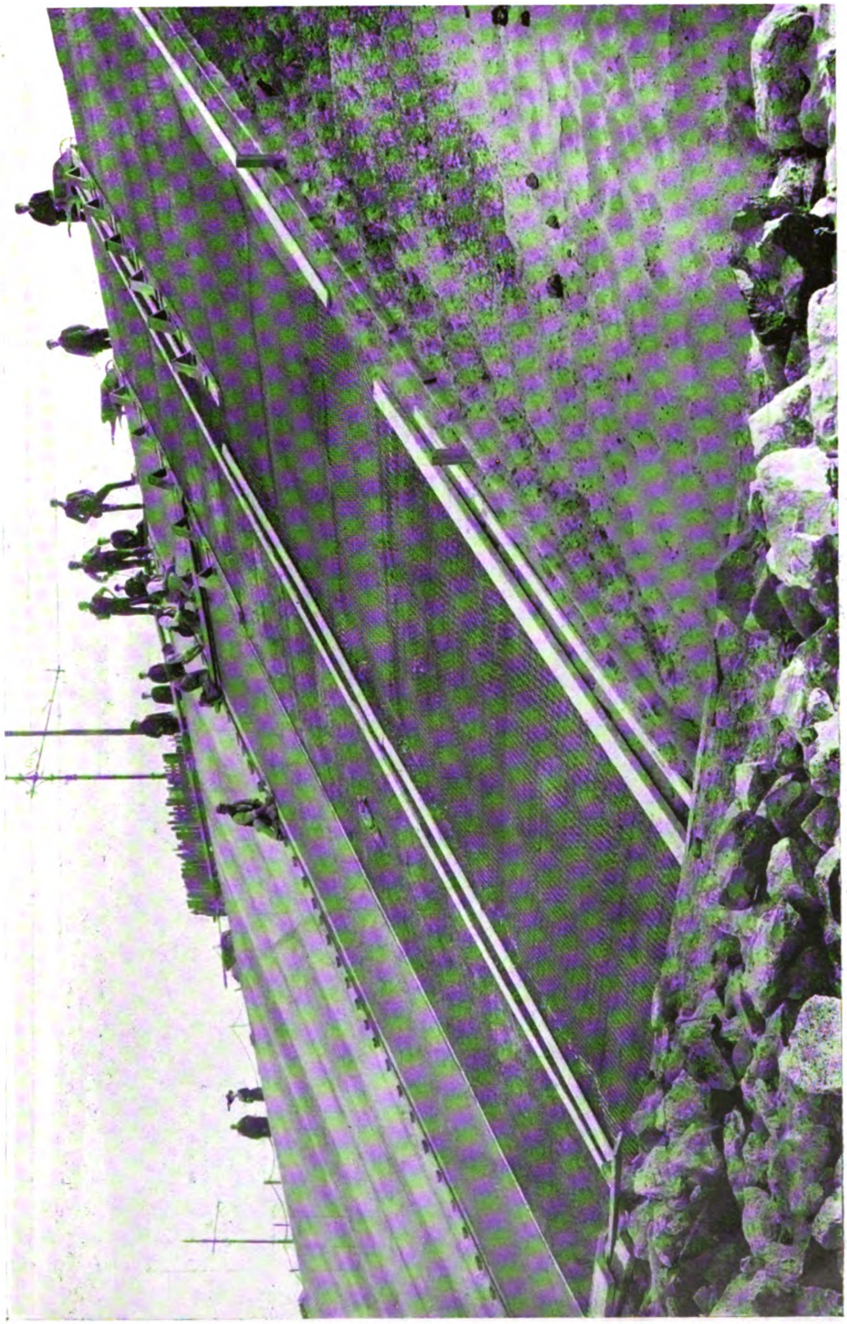
We present illustrations of some useful sea defence work executed by Messrs. Hardy and Atkinson, of West Hartlepool, on the New Expanded Metal Company's system, Mr. Nelson F. Dennis, the Borough Surveyor, having the credit of designing the structure on these up-to-date and most economical lines.

The illustrations explain themselves.

Temporary timbering was used for the retaining wall portion of the work, and after it had been removed, the earth was



Sea Defence Works near West Hartlepool.
Retaining Wall in Course of Construction.

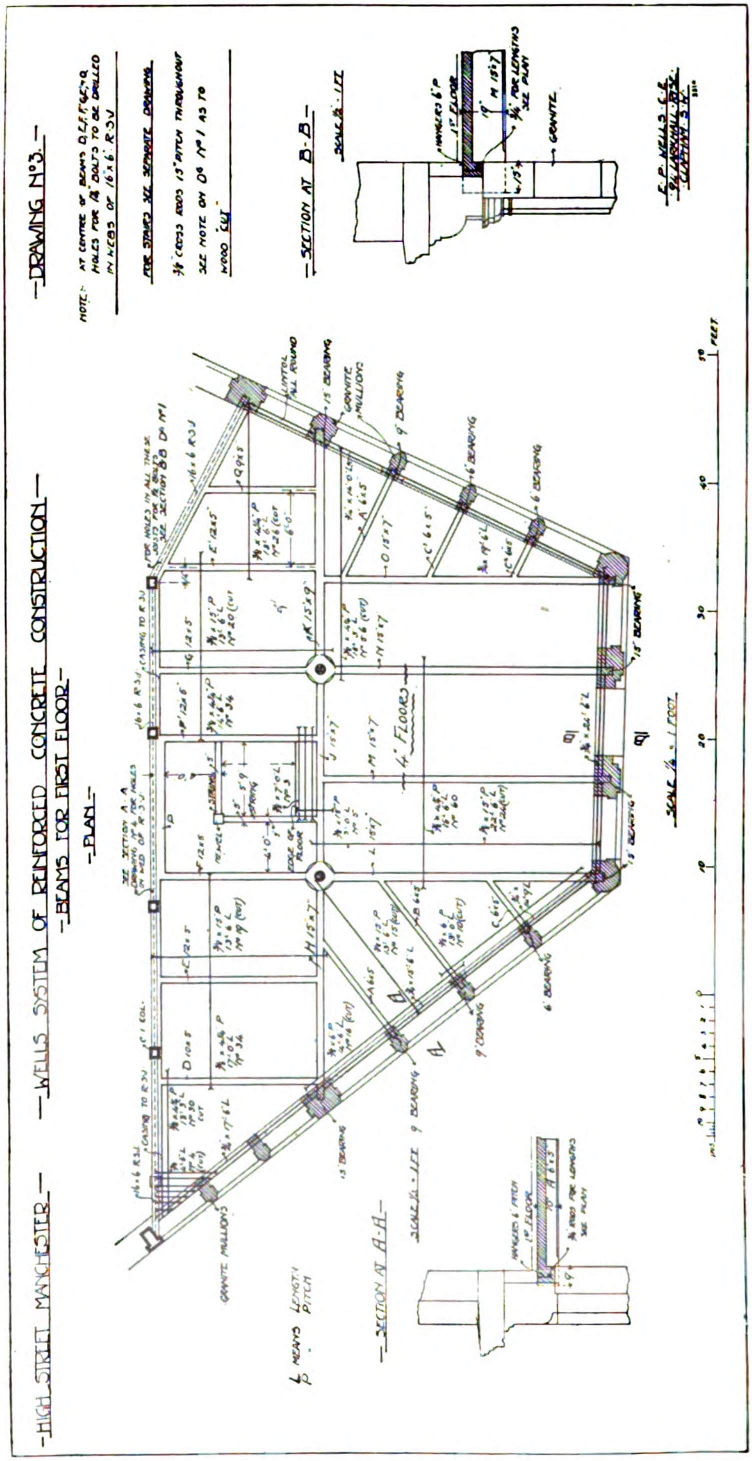


SEA DEFENCE WORKS NEAR WEST HARTLEPOOL.
Shows Long Slope at West Hartlepool End in Course of Construction.

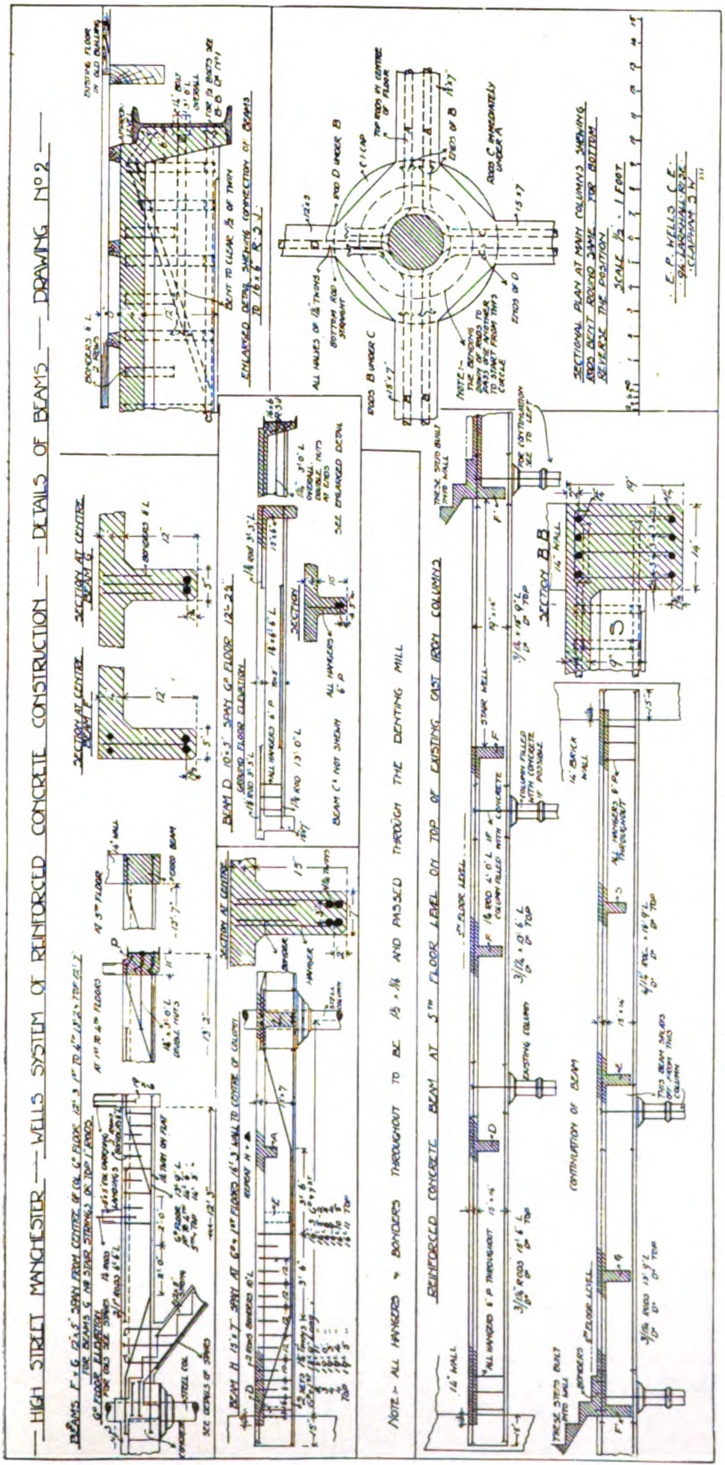
filled in and well rammed behind the face of the wall. For the slope generally, however, the bank was simply prepared to the correct angle, and the expanded metal lathing and concrete laid directly upon it.

NEW WAREHOUSE IN HIGH ST., MANCHESTER.

THIS building is to be used as a soft goods warehouse, and is composed of seven floors and a roof, the whole of which are of reinforced concrete. The floors are to carry an inclusive load of 2½ cwts. per superficial foot, and the roof an inclusive load of one cwt. The columns of these buildings are in solid steel, as it was found advisable to use this in place of reinforced concrete, owing to the exigencies of space. The columns are not



REINFORCED CONCRETE WAREHOUSE, HIGH STREET, MANCHESTER.


HIGH STREET MANCHESTER — WELLS SYSTEM OF REINFORCED CONCRETE CONSTRUCTION — DETAILS OF BEAMS — DRAWING No 2
SECTION AT CENTRE BEAM F
SECTION AT CENTRE BEAM G
ENLARGED DETAIL SHEWING CONNECTION OF BEAMS TO 16.6 R.S.J.
SECTIONAL PLAN AT MAIN COLUMNS SHEWING ROD BENT ROUND SAME FOR BOTTOM REVERSE THE POSITION
SCALE ½ : 1 FOOT
E. P. WELLS C.E.
CLAPHAM S.W.
NOTE:- ALL HANGERS & BENDERS THROUGHOUT TO BE ½ x 1/16 AND PASSED THROUGH THE DENTING MILL
REINFORCED CONCRETE BEAM AT 5TH FLOOR LEVEL ON TOP OF EXISTING CAST IRON COLUMNS
SECTION B.B
CONTINUATION OF BEAM

Reinforced Concrete Warehouse, High Street, Manchester.

jointed together at the junction of the floors, but let into the surrounding concrete, binding the same together. The staircase throughout is in reinforced concrete, the newel and the short columns being reinforced, as well as the stairs. The concrete throughout is composed of broken brick, broken down to ¾ of an inch, from which all the dust has been screened, mixed with sand made from Bramley Fall stone. The strength of the concrete is stated to be 170 tons per square foot and one month old, which will give about 250 tons per foot at four years.

The whole of the work has been carried out by Stuart's Granolithic Stone Company, Ltd. This Company is at present engaged in a number of works of a similar nature, all of which are being designed on the Wells system, under the personal supervision of Mr. E. P. Wells. The architect for the building is Mr. Rhodes Calvert, of Bradford.

NEW USES FOR CONCRETE

AT HOME AND ABROAD.

Under this heading reliable information will be presented as to new uses to which concrete and reinforced concrete are put, with data as to experience obtained during the experimental stage of such new applications of these materials. The use of reinforced concrete as a substitute for timber in exposed positions is one of the questions of the moment. Railway sleepers, telegraph posts, fence posts, etc., of concrete are being tried. Similarly, efforts are at present being made to prove that reinforced concrete is an excellent substitute for brickwork, where structures of great height are required.—ED.

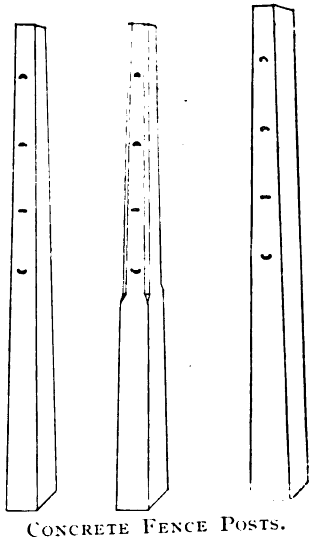
REINFORCED CONCRETE FENCE POSTS.

Comparison of Different Post Materials.

THERE is a constantly increasing demand for some form of fence post which is not subject to decay. The life of wooden posts is very limited, and the scarcity of suitable timber in many localities has made it imperative to find a substitute. A fence post, to prove thoroughly satisfactory, must fulfil three conditions: (1) It must be obtainable at a reasonable cost; (2) it must possess sufficient strength to meet the demands of general farm use; (3) it must not be subject to decay, and must be able to withstand successfully the effects of water, frost and fire. Although iron posts of various designs are frequently used for ornamental purposes, their adoption for general farm use is prohibited by their excessive cost. Then, too, iron posts exposed to the weather are subject to corrosion, to prevent which necessitates repainting from time to time, and this item will entail considerable expense in cases where a large number of posts are to be used.

At the present time the material which seems most nearly to meet these requirements is reinforced concrete. The idea of constructing fence posts of concrete reinforced with iron or steel is by no means a new one, but on the contrary, such posts have been experimented with for years, and a great number of patents have been issued covering many of the possible forms of reinforcement. It is frequently stated that a reinforced concrete post can be made and put in the ground for the same price as a wooden post. Of course, this will depend in any locality upon the relative value of wood and the various materials which go to make up the concrete post, but in the great majority of cases, wood will prove the cheaper material in regard to first cost. On the other hand, a concrete post will last indefinitely, its strength increasing with age, whereas the wooden post must be replaced at short intervals, probably making it more expensive in the long run.

FIG. e. FIG. f.



CONCRETE FENCE POSTS.

Figs. *e* and *f* showing Fence Posts with four tapering sides and two tapering sides.

In regard to strength, it must be borne in mind that it is not practicable to make concrete fence posts as strong as wooden posts of the same size; but since wooden posts, as a rule, are many times stronger than is necessary, this difference in strength should not condemn the use of reinforced concrete for this purpose. Moreover, strength in many cases is of little importance, the fence being used only as a dividing line, and in such cases small concrete posts provide ample strength, and present a very uniform and neat appearance. In any case, to enable concrete posts to withstand the loads they are called upon to carry, sufficient strength may be secured by means of reinforcement, and where great strength is required this may be obtained by using a larger post with a greater proportion of metal, and well braced, as is usual in such cases. In point of durability, concrete is unsurpassed by any material of construction. It offers a perfect protection to the metal reinforcement, and is not itself affected by exposure, so that a post constructed of concrete reinforced with steel will last indefinitely, and require no attention in the way of repairs.

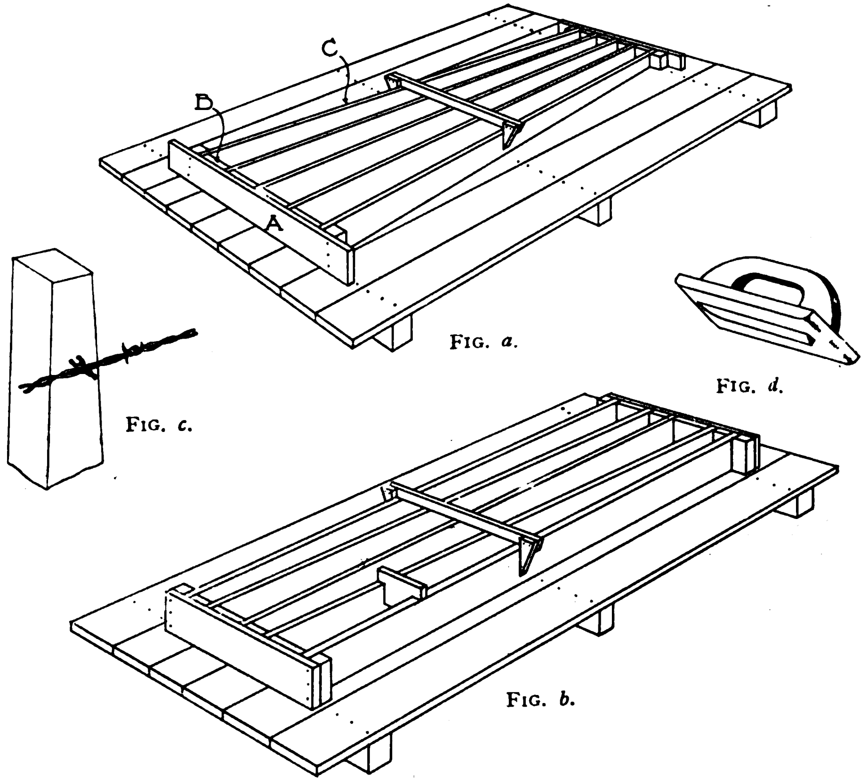


FIG. *a*.

FIG. *d*.

FIG. *c*.

FIG. *b*.

CONCRETE FENCE POSTS.
Moulds for making Fence Posts, with Fig. *a* four tapering sides ; Fig. *b* two tapering sides.
Fig. *c* shows method of fixing ; Fig. *d* tool for bevelling edges of posts.

Reinforcement.

No form of wooden reinforcement, either on the surface or within the post, can be recommended. If on the surface the wood will soon decay, and if a wooden core is used it will in all probability swell by the absorption of moisture and crack the post. The use of galvanised wire is sometimes advocated, but if the post is properly constructed and a good concrete used, this precaution against rust will be unnecessary, since it has been fully demonstrated by repeated tests that concrete protects steel perfectly against rust. If plain, smooth wire or rods are used for reinforcement they should be bent over at the ends, or looped, to prevent slipping in the concrete. Twisted fence wire may usually be obtained at a reasonable cost, and is very well suited for this purpose. Barbed wire has been proposed and is sometimes used, although the barbs make it extremely difficult to handle. For the sake of economy the smallest amount of metal consistent with the desired strength must be used, and this requirement makes it necessary to place the reinforcement near the surface, where its strength is utilised to greatest advantage, with only enough concrete on the outside to form a protective covering. A reinforcing member in each corner of the post is probably the most efficient arrangement.

Concrete for Fence Posts.

The concrete should be mixed with Portland cement in about the proportion 1–2½–5, broken stone or gravel under one-half inch being used. In cases where the aggregate contains pieces smaller than one-fourth inch, less sand may be used, and in some cases it may be omitted altogether. A mixture of medium consistency is recommended on the ground that it fills the molds better, and with less tamping than if mixed quite dry.

Moulds for Fence Posts.

Economy points to the use of a tapering post, which, fortunately, offers no difficulties in the way of moulding. All things considered wooden moulds will be found most suitable, for they can be easily and quickly made in any desired size and form. Posts may be moulded either in a vertical or horizontal position, the latter being the simpler and better method. If moulded vertically, a wet mixture is necessary, requiring a longer time to set, with the consequent delay in removing the moulds. *Fig. a* shows a simple mould, which has been used with satisfactory results in this laboratory, This mould has a capacity of four posts. but larger moulds can easily be made on the same principle. It consists of two end pieces (*a*) carrying lugs, (*b*) between which are inserted strips (*c*). The several parts are held together with hooks and eyes, as shown in *Fig. b*. To prevent any bulging of the side strips they are braced, as illustrated. Dressed lumber at least 1 in. thick, and preferably 1½ in. should be used. In *Fig. b* the post measures 6 in. by 6 in. at the bottom, 6 in. by 3 in. at the top, and 7 ft. in length, having two parallel sides. If it is desired to have the posts square at both ends the mould must be arranged as in *Fig. a*. This latter form of post is not as strong as the former, but requires ess concrete in its construction. Great care in tamping is necessary to insure the corners of the mould being well filled, and if this detail is not carefully watched, the metal, being exposed in places, will be subject to rust.

Attaching Fence Wires to Posts.

Various devices have been suggested for attaching fence wires to the posts, the object of each being to secure a simple and permanent fastener or one admitting of easy renewal at any time. Probably nothing will answer the purpose better than a long staple or bent wire well embedded in the concrete, being twisted or bent at the end to prevent extraction. Galvanised metal must be used for fasteners since they are not protected by the concrete. A piece of small flexible wire, about 2 in. in length, threading the staple and twisted several times with a pair of pliers, holds the line wire in position (*Fig. c*).

Moulding and Curing Posts.

Only so much concrete should be mixed at one time as can be used before it begins to harden ; but if an unavoidable delay prevents the posts being moulded until after the concrete has begun to set, it is thought that a thorough re-gauging with sufficient water to restore normal consistency will prevent any appreciable loss of strength, though the concrete may have been standing one or two hours. In using a mould similar to those illustrated in *Figs. b* and *a*, it is necessary to provide a perfectly smooth and even platform of a size dependent upon the number of posts to be moulded. A cement floor, if accessible, may be used to advantage. The moulds, when in place, are given a thin coating of soft soap, the platform or cement floor serving as bottom of mould being treated in the same way. About 1½ in. of concrete is spread evenly over the bottom and carefully tamped, so as to reduce it to a thickness of about 1 in. A piece of board cut as in *Fig. b* will be found useful in levelling off the concrete to the desired thickness before tamping. On top of this layer two reinforcing members are placed about 1 in. from the sides of the mold. The molds are then filled and tamped in thin layers to the level of the other two reinforcing members, the fasteners for fence wires being inserted during the operation. These reinforcing members are adjusted as were the first two, and the remaining 1 in. of concrete tamped and levelled off, thus completing the post so far as molding is concerned. To avoid sharp edges, which are easily chipped, triangular strips may be placed in the bottom of the mould along the sides, and when the moulds have been filled and tamped, similar strips may be inserted on top. The top edges may be bevelled with a trowel or by running an edging tool having a triangular projection on its bottom along the edges. Such a tool is shown in *Fig. d*, and can easily be made of wood or metal. It is not necessary to carry the bevel below the ground line.

The ends and sides of the mould may be removed after 24 hours, but the posts should not be handled for at least one week, during which time they must be well sprinkled several times daily and protected from sun and wind. The intermediate strips may be carefully withdrawn at the end of two or three days, but it is better to leave them in place until the posts are moved. Although a post may be hard and apparently strong when one week old, it will not attain its full strength in that length of time, and must be handled with the utmost care to prevent injury. Carelessness in handling green posts frequently results in the formation of fine cracks, which, though unnoticed at the time, appear later in the failure of the post.

Posts should be allowed to cure for at least sixty days before being placed in the ground, and for this purpose it is recommended that when moved from the moulding platform they be placed upon a smooth bed of moist sand and protected from the sun until thoroughly cured. During this period they should receive a thorough drenching at least once a day.

A coating of mineral oil or shellac may be used instead of soap to prevent the cement from sticking to the forms. As soon as the moulds are removed they should be cleaned with a wire brush.

The cost of reinforced concrete fence posts depends in each case upon the cost of labour and materials, and must necessarily vary in different localities. An estimate in any particular case can be made as follows: One cubic yard of concrete will make 20 posts measuring 6 in. by 6 in. at bottom, 6 in. by 3 in. at top, and 7 ft. long, and if mixed in the proportions 1–2½–5, requires approximately—

1·16 barrels of cement, at $2 ..	$2.32
0·44 cubic yard of sand, at 75 cents	·33
0·88 cubic yard of gravel, at 75 cents[*]	.66
Materials for 1 cubic yard concrete	$8.31
Concrete for one post	.17
28 ft. of 0·16 in. steel wire, at 3 cents per pound	.06
Total cost of concrete and metal for one post	$.23

To this must be added the cost of mixing concrete, moulding and handling posts, and the cost of moulds, an addition which should not in any case exceed 7 cents, a total of 30 cents per post.

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[*] One dollar = approximately 4s. 1d.; one cent = about ½d.

LAWS, RULES, AND REGULATIONS

AT HOME AND ABROAD.

The necessity of framing special regulations for the control of buildings and constructional works of concrete and of steel is being generally recognised, and new codes of rules are being issued in different parts of the world by governments, municipalities, underwriters, and estates. Important Laws, Rules, and Regulations will be published in full or in extract under this heading, for they will not only serve as a guide to those who assist in the preparation of such measures, but also to those engineers and architects who, in the absence of regulations, are anxious to safeguard the interests of their employers by specifying their work to meet the eventualities of time or unusual strain.—ED.

INSTRUCTIONS TO INSPECTORS as to REINFORCED CONCRETE ARCH CONSTRUCTION ON NEW RAILWAY WORKS.

THE following comprehensive instructions to reinforced concrete arch inspectors will be of interest and possible direct value to many engineers engaged in reinforced concrete construction.

They were issued in the first instance by Mr. Geo. P. Carver, Divisional Engineer, Florida East Coast Railway.

This railway, as is widely known, has a great length of reinforced concrete arch viaduct. The instructions are as follows :—

Inspectors will be required to become familiar with, and carefully follow out, the following instructions regarding inspection, and see that the work is carried out in strict accordance with same. An inspector will be required to be on the work during the setting of forms, placing of reinforcement, and the mixing and placing of concrete. He will represent the Engineer-in-Charge, and will be held responsible for the correct performance of the work assigned to him. He will, in a general way, carefully and continuously watch the progress of the work, making a record of the amount of work done each day and the manner in which it is done.

He will be required to become thoroughly familiar with the plan of the work which he is inspecting, that he may intelligently perform the duties entrusted to him. He will be required to fill in a daily report sheet, printed forms being furnished for this purpose, giving the location of the work, the amount of work done, the number of batches mixed and placed, the proportions used, the arrival of material and all such other information as will assist in making a concise and accurate record of the progress and cost of the whole or any part of the work. He will see that the following specific instructions are carried out :—

Forms.

That the forms are properly set up and braced.

That the concrete face of the forms is given a coat of oil applied with a brush.

That an excess of oil is not used.

That the forms are cleaned at each setting and recoated with oil.

That the forms are correctly placed, allowing the depth, width and batter called for on the plans.

That the inside of the forms is free from débris (shaving, sawdust, blocks of wood, etc.) just previous to pouring.

That the forms are properly held together with No. 9 wire or rods of suitable dimensions, and temporary spacing pieces are used and removed when the concrete reaches their height.

That the joints formed by the edges of the lagging are tight, so that grout will not escape, and that such defects are remedied by the use of plaster of Paris, calking, strips of wood or other suitable approved method.

That the arch centres are lowered sufficiently to allow the arch ring to assume its permanent set before spandrel walls are poured, in this manner reducing the possibilities of cracks occurring in spandrel walls because of possible excessive settlement in crown of arch ring.

Steel Reinforcement.

That the correct number and size of reinforcing bars are used, and that they are placed as shown on plan.

That all steel used is free from loose or scaly rust. (A thin film of rust will not cause the rejection of a bar.)

That bars covered with loose, scaly rust are cleaned with a stiff wire brush or given a pickling bath of a sulphuric acid solution (consisting of 1 part acid to 6 parts of water) and dipped in clean water.

That the intersection of the rods are wound with a length of No. 18 wire in a sufficient number of places so that the whole steel reinforcement will be fabricated sufficiently strong and rigid to withstand the placing of concrete about the steel, and without disturbing the position of same.

That the bars are spaced the proper distance apart, and away from the face of the form work, and are secured properly and held in that position in such a manner that they will not be disturbed by the placing of concrete.

That all protruding bars from piers and arches to which other bars are to be spliced, and which will be exposed to the action of the weather for an indefinite period are, protected from rusting by a coat of thin, neat cement grout.

That the position of the steel is not disturbed during pouring.

Placing Concrete.

The inspector will see that the specified proportions of material are used in mixing the concrete.

That the concrete is of the proper consistency.

That an accurate account is kept of the number of batches mixed, the same to be recorded on a printed card which will be furnished for that purpose.

That these batch record cards are preserved and filed for future reference.

That in placing the concrete the same will be done in a careful manner, and precautions taken not to allow the concrete bucket to come in contact with the form work.

That care is taken not to jar the form work until the concrete work is hardened.

That in making a bond between old and new work care is taken to thoroughly clean the surface of the old concrete (preferably by a jet of steam), and that a thin layer of a 1 to 1 grout is spread to assist in making a good bond.

That the surface of the concrete which is to be bonded to other concrete is left in a rough condition, either by spreading a layer of broken stone over the same, running half the depth of the stone into the green concrete and leaving the upper half of the stone protruding, or by setting in strips of wood, which, when removed, will form a groove and assist in making a good bond.

That in bonding the spandrel wall with the arch ring, a groove or ridge is formed on arch rings running under and with spandrel wall to prevent water from centre filling to run through and down the face of arch ring, discoloring same.

That in placing dry concrete the same is thoroughly compacted with suitable approved iron tamps.

That in pouring wet concrete the same is thoroughly spaded, rodded and worked with suitable tools sufficiently to cause all air bubbles to escape, to work grout to face of form work, filling all voids and showing a smooth, well-mixed concrete free from voids when forms are removed.

That a fine mixture of 1 to 3 is deposited around and among the bars, and that it is thoroughly worked in and around the bars in such a manner that the steel will be completely surrounded, embedded and covered.

That all concrete is deposited in forms within 30 minutes after leaving mixer.

That all exposed surfaces of concrete are kept continually wet for a period of ten days after removal of forms.

In General.

A record book will be furnished the inspector, in which a record will be kept of the progress of the work, and the following information should be recorded : Date ; time of day of each entry ; day or night work ; number of men ; foreman ; condition of forms ; condition of steel ; number and location of lights (if night work) and if properly lighted ; number, time and location of test cubes taken ; rate of mixing ; size and number of batches ; proportions of mixture ; name and number of work barge ; arrival of material ; kind and amount and on what barge.

Inspectors will be required to fill in several daily report blanks that will be furnished.

Inspectors will receive further written instructions from the Engineer-in-Charge from time to time, and will attach same to these instructions and will consider them a part of same.

Care should be taken not to allow the first concrete placed to appreciably stiffen or set before the remaining concrete is placed. The remedy for this is to occasionally, as often as necessary, add a little more concrete to that already placed over all exposed surfaces.

Great attention is necessary to make each section (pier, arch ring or spandrel wall) monolithic in height, length and width. Only when circumstances render it practically unavoidable may the work be stopped before the entire section is completed.

Order and close attention to details is essential. Carelessness in proportioning, in mixing or compacting the materials, or the omission or misplacement of the steel bars, may cause defective or even destructive results. Reinforced concrete construction requires close, continuous and intelligent supervision.—*Engineering News, U.S.A.*

NEW BOOKS

AT HOME AND ABROAD.

We are making special arrangements as to the reviewing of books. Pending the completion of these arrangements, occasional notices will appear, of which the following is the first. We shall accord special attention to foreign books.—ED.

SOME GERMAN BOOKS.

Der Eisonbetonbau. [*Reinforced Concrete Construction.*] **C. Kersten. With 100 diagrams. Ernst U. Sohn, Berlin.**

The issue of the Prussian official regulations for reinforced concrete construction in 1904 has given rise to the publication of various manuals designed to assist the engineer and builder in the carrying out of this type of constructional work, the employment of which has made such great strides in Germany during the last few years. The official formulæ enable the strength of a given structure to be calculated, but in designing a building it is the converse problem which is of importance, namely, to determine the dimensions of the structural members, best proportion and distribution of the reinforcement, etc., in order to sustain a given load. The greater portion of the book before us has this object. Taking the form of a running commentary on the official regulations, the simple theory of each form of beam, column, arch, or decking, is discussed, the means of arriving at the moments concerned are explained, and formulæ are given for determining the required dimensions, worked examples being added. No mathematics beyond the use of simple algebraical formulæ is introduced. The presentation is admirably clear throughout, and the work should be of great assistance to all engaged in the design of reinforced concrete constructions.

The first section of the book is devoted to an account of the preparation and properties of the materials employed. The paragraphs dealing with Portland cement are, perhaps, too brief and sketchy to be of much practical value. There is a curious blunder on page 15, where Portland cement is correctly stated to have a specific gravity of 3·13—3·25, whilst that of Roman cement is given for comparison as 0·82—1·27, the latter figures representing, of course, not the specific gravity, but the apparent density when filled into a measuring vessel and weighed in air. The only cement testing method described is that of Ritter, and, in view of the frequent adulteration of Portland cement in Germany with slag and other cements, and the difficulty of detection, the user is recommended to trust rather to the mark of firms of established reputation than to the results of hastily carried out tests.

The preparation of the concrete is described in somewhat greater detail. English readers may be warned that the "tonne" of cement mentioned on p. 32, and again in the cost tables on pp. 160-163, does not refer to the metric ton, but to the cask of cement of 170 kilogrammes.

It remains to be said that the book is well printed, and that the use of different types in the formulæ facilitates reference.

Die Scher-und Schubfestighelt des Eisenbetons. [*The Shearing Strength of Reinforced Concrete.*] **By S. Zipkes. Ernst U. Sohn. Berlin.**

Although a fairly general agreement has been reached on the question of the resistance of reinforced concrete to tension, compression and bending, this is far from being true of the important problem of its resistance to shear. One cause of this is the difficulty of arranging experiments in such a way as to subject the test-piece to shearing stresses only, bending always occurring at the same time. Herr Zipkes' book, which is a slightly enlarged reprint of a series of articles which appeared in *Beton und Eisen*, contains a record of a number of tests on plain and reinforced concrete blocks carried out in the laboratory of the Technical High School at Stuttgart. Plain concrete blocks were found to show the first cracks under shear when one-fifth of the total load required for destruction had been applied. Blocks reinforced by means of looped steel rods required twice as great a load to destroy them as the plain blocks, further cracks not appearing until one-half of the total load had been applied. The rate at which the load is increased has a considerably influence, rapid loading giving a fallaciously high test.

CORRESPONDENCE.

Under this heading we invite correspondence.

REINFORCED CONCRETE FOR EARTHQUAKE DISTRICTS.

SIR,—The reports which are constantly coming in with regard to the effect of the earthquake and fire on San Francisco buildings are showing more and more clearly the hitherto almost unrecognised superior advantages of reinforced concrete for work which is liable to the shock of earthquakes, and to the devastating effect of fire. These advantages are described as being "unrecognized," but this lack of recognition was only on the part of the public, and those architects and engineers who had not had actual experience with regard to the "fireproofing" qualities of concrete, or who had not studied this subject, and the somewhat related one of the ability of reinforced concrete work to withstand shock. Engineers who *had* given this subject consideration prior to the recent catastrophe, knew that the little concrete work which was in existence in San Francisco would be sure to take the palm, when compared with brick and terra cotta, and that it would become the material recognised as being the best for reconstruction purposes in districts susceptible to earth tremors.

Early Tests for Shock.

Those who had studied the subject of vibration in concrete buildings knew its value from that point of view, and those who are acquainted with the literature on the subject will recall the results of the tests made by the engineers of the Paris and Orleans Railway Company, in Paris, in which a weight was dropped from a given height on a floor construction made of steel beams with brick arches, and the amplitude and time of vibration of the structure noted. Another weight twice as heavy was dropped from a height twice as great, on to a reinforced concrete floor, which weighed only 60 per cent. per square foot as much as the brick floor, and the amplitude of vibration was only one-fifth as much, and the vibration lasted only one-third as long as in the case of the steel and brick floor.

Concrete and Steel Structures in Mexico.

The "New York Times" of April 23rd (only four days after the earthquake) commented in its main editorial upon the description given by a correspondent of the method after which the Capitol of Mexico had been designed, so as to preclude the possibility of damage from earthquake. The edifice is to be erected with a general skeleton of steel columns and beams, and this entire skeleton of steel will be completely embedded in a concrete made of a light volcanic rock resembling coarse pumice stone mixed with the proper portions of cement. The concrete will be strong enough to support the steel, and this steel will form a gigantic basket work strong enough to support the concrete, and prevent cracks forming under strains due to terrestrial disturbances.

Reinforced Brickwork in Japan.

Long before the San Francisco earthquake the Japanese had noted the marked advantages inherent in reinforced concrete, and it is understood that engineers from that progressive country have instituted a series of tests, in which small structures are mounted upon tables capable of being vibrated in the same way in which an earthquake would shake a similar structure, and the effect of various kinds and durations of shock carefully studied.

Reinforced Brickwork at San Francisco.

The survival after earthquake and fire of the walls of the Palace Hotel in San Francisco is in a large measure a demonstration of the value of reinforced work in the withstanding of earthquakes. In it the brick walls are tied together by embedded iron rods, so that the work was practically "reinforced brick work," in a sense somewhat like "reinforced concrete." It is evident that even with the best of workmanship, since brick work is made of separate blocks, cemented together, it cannot begin to possess the advantages of concrete, properly reinforced, in which the whole mass, when properly mixed and deposited, becomes a monolithic structure.

Reinforced Concrete as a Fire Resistant.

As to concrete, on the side of a fire-protecting or fire-retarding material, the reports being made by American surveyors to the various insurance companies stand without question. The American experts in fire protection connected with these insurance companies long ago recognised the value of reinforced concrete buildings from an insurance standpoint, or of proper aggregate, or affording due protection to the metal rods, and at the present time probably the lowest insurance rates to be found anywhere in the United States on mercantile buildings are on a series of tenant factory buildings in Brooklyn, New York, built of reinforced concrete, where this form of construction is coupled with sprinkler equipment, wire glass supported in metal frames throughout, etc.

Lessons as to Protection of Columns.

Attention should be specially called, however, to a point to which sufficient importance has not as yet been attached, namely, to the superiority of solid concrete column protection over any form of fireproofing which contained an air space. Quiet air had always been considered as the most perfect insulator obtainable, but such instances as occurred in the basement of the Aronson Building, San Francisco, in which columns protected with air space buckled, while others in the same basement which stood all strains were encased in solid concrete, is ample proof of the value of the later method of fireproofing.

In Conclusion.

In justice to the more progressive members of the great technical professions, it is thus, perhaps, only fair to mention that the excellent qualities of concrete and reinforced concrete, the advantages of reinforcement generally, both for shock, vibration, and fire resistance were realised before the great catastrophes of this year, and further, that it appears that just before the catastrophe occurred which devastated San Francisco, engineers all over the world were turning to reinforced concrete as the solution of their difficulties with regard to both earthquakes and fires.

Yours truly,

E. P. Goodrich, Mem. Am. Soc. C.E.,

General Manager Underwriters' Engineering and Construction Company.

SOME SUBJECTS DEALT WITH IN No. I.

The Advent of the Concrete Age..	Lieut.-Col. E. A. Winn, R.E.
Steel Skeleton Construction and the London Building Acts .	W. Noble Twelvetrees, M.Inst. M.E.
Reinforced Concrete Construction	Charles F. Marsh, M.Inst.C.E.
The Setting of Portland Cement..	Cecil H. Desch, D.Sc.
The Preservation of Iron and Steel	B. H. Thwaite, C.E.
Reinforced Concrete at Munich (The New "Tietz" Stores)..	

Impending Conferences on Reinforced Concrete—The Fire Resistance of Concrete—Fictitious Portland Cement—Safeguards against Freezing in Concrete Construction—Concrete Railway Sleepers in U.S.A.—New York Rules on Reinforced Concrete—German Portland Cement Manufacturers—A Reinforced Concrete System with Rigid Shear Members.

SOME SUBJECTS DEALT WITH IN No. 2.

Reinforced Concrete in the United States..	Capt. Sewell, U.S.A.
Reinforced Concrete Piles in Tidal Waters	A. T. Walmisley, M.Inst.C.E.
Reinforced Concrete on the G.W.R.	W. Armstrong, M.Inst.C.E.
Hollow Concrete Block Building	S. B. Newberry, Cleveland, U.S.A.

The R.I.B.A. and Reinforced Concrete—Fictitious Portland Cement—The Merchandise Act—Reinforced Concrete Roofs in Egypt—A Reinforced Concrete Bridge at Indiana, U.S.A.—Water Tower at Bournemouth—Flow of Concrete under Pressure—Fire Tests with Reinforced Concrete—Loose Stirrups *versus* Rigid Shear Members in Reinforced Concrete Beams.

ARTICLES AND PAPERS

AT HOME AND ABROAD.

The following articles and papers are among the most important published at home and abroad during August and September of 1906 :—

I.—CONCRETE CONSTRUCTION.

Articles.

A Method of Mixing and Laying Bituminous Concrete for Mill Floors. By C. H. Chadsey : describing an improved system of dealing with a form of tar concrete possessing the special advantages of solidity, durability and impermeability, and therefore particularly suitable as a base for wood-covered floors in industrial establishments and public buildings.—*Eng. News*, 2.8.06.

Estimating for Excavation and Concrete Work : a note and some points to which the writer considers more attention should be given by builders and contractors, and subsequent correspondence relative to the note.—*Bldr.*, 15.9.06, 22.9.06, 29.9.06, and 6.10.06.

Construction of a Tube Railway : a series of *ill.* articles, of which the following is an outline synopsis :—I. Preliminary Works. II. Break-up Chambers, Headwalls. III. Tunnelling with a Shield.—*Bldr.*, 4.8.06., 1.9.06 22.9.06.

II.—REINFORCED CONCRETE CONSTRUCTION.

Articles.

Massive Plates with Crosswise Reinforcement. By H. Froelich,—*Beton u. Eisen*, *Aug.*, 1906.

Reservoirs for the "Intercommunale du Centre." By O. Amiras, Ghent : a pair of cylindrical reinforced concrete reservoirs at the Chaussée de Mariemont, Houdeng, Belgium.—*Beton u. Eisen*, *Aug.*, 1906.

Replacement of Wooden Shaft Lining in a Coal-Mine by Reinforced Concrete. By Mine Inspector Hundt, Neunkirchen : the William shaft No. 2 of the Konig State Coal Mine at Neunkirchen, was formerly lined with wood. The lining having decayed has been replaced by a lining of reinforced concrete, 24 cm. thick. Detailed constructional drawings are given.—*Beton u. Eisen*, *Aug.*, 1906.

Reinforced Concrete Sea-Coast Scarp. By de Muralt, Zierilezee, Holland : the basalt dykes at Scheumen in Holland, having been found defective in heavy storms, have been replaced by a reinforced concrete scarp, consisting of a stepped platform attached to reinforced concrete piles. Interesting photographs and details of construction are given. The cost (sand being at hand) was less than M. 6 per sq. metre, against M. 8·35 for basalt. The new dykes have stood well in heavy storms.—*Beton u. Eisen*, *Aug.*, 1906.

Reinforced Concrete Gas Holder Tank at Dubuque U.S.A. : *ill.* description of a reinforced concrete cylindrical tank 84 ft. diameter by 21 ft. 5 in. deep, a construction affording a good example of a carefully planned method of work in erection, and illustrating the application of expanded metal and corrugated bars as reinforcement.—*Eng. News*, 9.8.06.

A New Experimental Method of Determining the Location of the Neutral Axis in Reinforced Concrete Beams. By F. D. Warren : the new method suggested is, unlike methods usually adopted, a direct method of locating the neutral axis, and is governed by accepted laws of mechanics. The writer has tested two reinforced concrete beams by this method, with satisfactory results. From these two tests it appears that the location of the neutral axis may be divided into distinct stages, as follows :—During the first, before the effect of the steel comes into action the axis appears to be at or near the centre of the depth, and during the second the neutral axis lowers until all the tension is resisted by the steel ; during the third, the position of the neutral axis remains practically constant, and continues so until the elastic limit of the steel is reached ; and finally the position rises rapidly during the elongation of the steel until fracture occurs by crushing of the upper fibres of the concrete.—*Eng. News*, 23.8.06.

Reinforced Concrete Work on the New Austrian State Railways. By August Nowak : a detailed account, with full page and folding plates, of bridges, retaining walls, etc., of reinforced concrete on the Austrian railways.—*Beton u. Eisen*, *Aug. and Sept.*, 1906.

Semi-Reinforced Concrete : the low price of cement and the high price of steel in Italy have led to the introduction of the Pesenti system of building, in which concrete is used with only occasional reinforcement in important parts.—*Le Ciment*, *Sept.*, 1906.

Buildings on the Lund System. By A. Maciachini, Milan.—*Beton u. Eisen*, *Sept.*, 1906.

Reinforced Concrete Shaft-Partitions. By — Nast at the Nordstern mine at Horst-Emscher and at the Graf Schwerin mine at Castrop, Westphalia, partitions for separating the winding and ventilating shafts from one another have been constructed of reinforced concrete, the thinness of the partition thus made possible affording greater working room.—*Beton. u. Eisen*, *Sept.*, 1906.

An Eight-Track Reinforced Concrete Viaduct in Winnipeg, Manitoba : the structure here described and *ill.* carries eight tracks on the Can. Pac. Rly. crossing Main Street, Winnipeg, overhead at an angle of 86 deg. 4 min., and is of interest both on account of the special design of the concrete groined arches, and from the character of the reinforcement, which consists of old rails bolted and trussed together to resist stresses in flexure, tension, and shear. The small depth of the arch crowns is also worthy of note, especially in consideration of the fact that the tracks are carried over them in ballasted troughs.—*Eng. Rec.*, 15.9.06.

A Reinforced Concrete Tunnel Caisson. I. : the work described in this article is one of the three caissons used in the construction of the Hudson River tunnel system. The caisson is trapezoidal in plan, about 101 ft. long and from 23 ft. 6 in. to 46 ft. wide, the extreme height being about 51½ ft., and the total weight of the structure about 13,300,000 lb. It consists essentially of a monolithic mass of concrete, containing upper and lower chambers with solid concrete masonry round them. The concrete walls have a minimum thickness of 3 ft., the roof and deck arches are 3 ft. thick at the crown, and are reinforced by longitudinal and transverse twisted steel bars, the roof being additionally reinforced by horizontal rails parallel with the axis of the arch.—*Eng. News*, 29.9.06.

A Large Reinforced Concrete Standpipe : particulars taken from a paper read by Mr. George H. Snell before the New England Waterworks Assn. relative to the reinforced concrete standpipe 50 ft. dia., 106 ft. high from the inside of the bottom of the tank to the top of the cornice, and with the capacity of 1,500,000 gall., recently completed at Attleboro', Mass. The details given as to construction and the measures taken for rendering the reservoir watertight are of special interest.—*Eng. Rec.*, 29.9.06.

III.—STEEL CONSTRUCTION.

Articles.

An Office Building, 612 ft. Tall: description of the steel-framed masonry tower, about 65 ft. sq., and carried to the height of 612 ft. above pavement level, which will constitute the chief feature in the extension of the Singer Bldg., New York. Notwithstanding its small transverse dimensions, this portion of the new building will furnish a floor area of 9½ acres and accommodation for about 6,000 persons.—*Ill. Sc. American*, 6.9.06.

Comparative Designs of Steel and Reinforced Concrete for Cantilever Foundation Girders: a short article showing the economy attained by the substitution of cantilevers and distributing girders of reinforced concrete in place of steel cantilevers and I-beam grillages for supporting the columns in the additional buildings of the Boston Athletic Assn.—*Eng Rec.*, 1.9.06.

IV.—MATERIALS, TESTS, AND FORMULÆ.

Articles.

Calculation of the Dimensions of Doubly Reinforced Beams. By Carl Drach: a series of formulæ and tables for calculating the dimensions of beams reinforced in the upper and lower portions.—*Beton u. Eisen, Aug.*, 1906.

Loading Tests of Visintini Beams for Railway Bridges in Denmark. By Sophus M. Andersen, Copenhagen—*Beton u. Eisen, Aug.*, 1906.

Hollow Concrete Blocks. By — Albrecht, Berlin a continuation of former articles.—*Beton u. Eisen, Aug.*, 1906.

The Production of Portland Cement in the United States for 1905: summary of statistics contained in a bulletin recently published by the Division of Mineral Resources of the U. S. Geological Survey, and prepared under the direction of Mr. E. C. Eckel, A.M.Am., Soc.C.E. The article includes a table containing data on the production of Portland cement grouped according to the various combinations of raw materials used in its manufacture.—*Eng. News*, 23.8.06.

The Collapse of a Reservoir at Madrid. By Fritz von Emperger: this introductory article describes the tests made by the engineer of the Madrid reservoir on a smaller reservoir at Gijon. It was the success of this and other small reservoirs which induced their designer to attempt the much larger construction on the same lines, and succeeding articles will discuss the causes of the failure.—*Beton u. Eisen, Sept.*, 1906.

Concrete Paving Slabs in Berlin.—*Zement u. Beton*, 1.9.06.

Considère's Formula for Calculating Spirally Reinforced Concrete Columns, and Messrs. Wayss and Freytag's Experiments. By K. Heintel: the author's formulæ, based on Bach's tests, assign the chief part to the longitudinal rods, and not to the spiral reinforcement. In a note, M. Considère shows that this is only the case when the rules laid down by him for the spacing of the spirals are departed from. When the proper proportions are observed, the increase in strength is due mainly to the spirals.—*Beton u. Eisen, Sept.*, 1906.

Shearing Stresses in T-Beams. By Prof. Ramisch, Breslau.—*Zement u. Beton*, 15.9.06.

Tests of the Effect of Heat on Reinforced Concrete Columns. By Prof. H. B. MacFarland, Armour Inst. of Technology, Chicago. This article presents results of experiments made at the Chicago Laboratory of the National Fireproofing Co., the object being to determine (1) if a reinforced concrete column when subjected to a temp. of from 1,500 deg. to 1,600 deg. F. for a period of 3 hrs., would be impaired in strength or elasticity; (2) the effect of quenching with water a concrete column which had been highly heated; (3) that a reinforced concrete column encased in a fireproof material is not impaired in strength or elasticity, if subjected to a furnace temp. of 1,600 deg. F. for several hours. The results of the tests are summarised in tabular form. *Eng. News*, 20.9.06.

Note on the Resistance of Building Stones to Frost. By Prof. J. Malette, Paris: describing and discussing the Brard process and the modifications made in it by M. M. Vicat, Héricart de Thury, and Husson; the method proposed by M. Braun; and the manner in which the resistance of stone is determined in the present by successive variations of temperature.—*Ill. Bldr.* 15.9.06.

Building Stones and Frost. By W. R. Purchase: remarks from a practical point of view relative to the article by Prof. J. Malette in "The Builder" of Sept. 15th.—*Bldr.*, 29.9.06.

Gypsum and Its Occurrence in the Dove Valley. By Mr. T. Trafford Wynne: a paper giving a summary of the districts in the United Kingdom where gypsum is found in workable deposits and after quoting statistics relative to the output of gypsum in England, describes various methods of mining and production.—*The Inst. of Mining Engineers* (*Hanley Mtg.*).

V.—SPECIAL SUBJECTS.

Articles.

The Visintini System. By — Selinger and F. von Emperger: an illustrated description of a number of bridges constructed with Visintini beams.—*Beton u. Eisen, Sept.*, 1906.

Bridge at Bad Tölz: this reinforced concrete bridge, 31.5 metres long and crossing a ravine 15 metres in depth, is of remarkably light construction, T-beams being used as the nature of the ground was such that arches could not be employed.—*Beton u. Eisen, Sept.*, 1906.

Protection of River Banks below the Water-Level. By — Deutsch, Münster.—*Zement u. Beton*, 15.9.06.

A Four Span Reinforced Concrete Arch Bridge on the Southern Railway.—By H. C. Harrison: this structure, 300 ft. long by 26 ft. wide, is reinforced with Johnson corrugated bars and has been substituted for a steel bridge with masonry piers. The chief problem that had to be faced by the contractor was the transportation of materials, and it will be found on perusal of the article that the method here introduced and successfully used is entitled to a prominent place in the economy of concrete bridge erection.—*Eng. Rec.*, 22.9.06.

SOME SUBJECTS DEALT WITH IN No. 3.

The Historical Evolution of Reinforced Concrete in France ..	N. De Tedesco
Reinforced Concrete Bridges.—I.	W. N. Twelvetrees, M.Inst.M.E.
The Setting of Portland Cement.—II.	E. Candlot (Paris).
Reinforced Concrete Water Mains	R. H. Wyrill, M.Inst.C.E
The Theory of Reinforced Concrete	Captain Sewell (U.S.A.).

Recent Examples of Steel and Concrete Buildings in Scotland—Types of Hollow Concrete Blocks used in the States and their Patents—Concrete Ribbed Arch Footbridge over a Gorge—Reinforced Concrete Water Tower, Champagne-Sur-Seine, France—Reinforced Concrete Towers for Power Transmission Lines—Fire Tests with Reinforced Concrete Floors.

CONCRETE
AND
CONSTRUCTIONAL ENGINEERING

Volume I. No. 6. JANUARY, 1907.

EDITORIAL NOTES.

H. M. GOVERNMENT AND REINFORCED CONCRETE.

WHAT we announced as probable in our preceding issue has now become a fact, and we are authoritatively informed that His Majesty's Office of Works have decided to employ reinforced concrete for the General Post Office extension on the Christ's Hospital site. This important building, which will be carried out under the supervision of Sir Henry Tanner, I.S.O., should—if, as we anticipate, successfully and economically erected—have a far-reaching effect upon the introduction of reinforced concrete generally into the public buildings of the Empire, and we certainly congratulate the distinguished architect who has recommended this notable departure in the practice of His Majesty's Office of Works upon this forward step. The system to be applied is that of Messrs. Hennebique.

The weakest point in the application of reinforced concrete is the necessity for extreme care and supervision at every stage of the work, and, of course, it is in a Government building that such supervision can be best obtained on systematic lines. We thus look forward to some interesting particulars regarding the system to be adopted for the examination of materials, and supervision of the exact application of the rods in the position specified. We also anticipate with interest some of the practical details of the specification of this important work, among others more particularly those details referring to the thickness of concrete covering rods with the view to protection from fire and the definition of the concrete aggregates employed.

FAILURES IN REINFORCED CONCRETE.

FOLLOWING the policy expressed, we are again presenting an interesting example of a failure in reinforced concrete, so that the lessons in this case may be studied and learned. This instance is also taken from Switzerland, and a highly interesting report published from the pen of the eminent Professor Schüle, of Zürich, written in conjunction with Herr Elskes, of the Swiss Government Railways.

As in all fields of building construction, there are necessarily quite a number of accidents and failures in reinforced concrete work, and we consider it the business of a journal such as ours to present independent reports upon such failures, rather than follow the example of those many enthusiasts as to reinforced concrete who hold the publication of such particulars harmful to the development of this form of construction.

We further desire not only to describe cases of obvious failure, where buildings have actually collapsed, but also to be able to produce reports upon structures which, while clearly faulty, have only shown defects that are easily remediable.

DEFECTS IN REINFORCED CONCRETE THAT ARE REMEDIABLE.

To give an instance of such a case where a defect has made itself evident, we would mention the well-known reservoir at Newton-le-Willows, which was recently completed, but has not proved itself to be as water-tight as was desired. Here we have an instance of far-seeing building owners, whose permanent and consultant officers are of the highest standing, employing a reinforced concrete system of great popularity, and having their work executed by a firm of contractors of extremely wide experience; the whole of these parties, the employer, engineers, specialists and contractors, being desirous of doing their very best. Nevertheless, the result of their efforts so far is that they have apparently not quite realised their ideal, and that certain repairs, *i.e.*, certain internal linings, or perhaps even some slight partial reconstruction of a portion of the reservoir, may be deemed advisable with a view to attaining perfection. An independent description of the defects, if any, would in such a case be a most valuable contribution to these columns.

INDEPENDENT ENQUIRIES ON MATTERS OF TECHNICAL IMPORTANCE.

Now this is also an example where independent enquiry into the design, the materials, and the other facts of the case would be of the highest possible importance to engineers, architects and contractors alike, but unfortunately there is no machinery apparently available for such public investigation into the technical aspect of similar instances.

What we should thus like to see, in respect to technical questions arising in the construction of public works, is the machinery we find in some of the Continental Governments, where certain public departments have the necessary powers to institute an enquiry into technical matters in the public interest; and enquiries something on the lines of those held by the Board of Trade on railway accidents, or under the Home Office into explosions and the like, are not only regularly held but prove to be extremely valuable.

We can hardly describe a case such as this defect at Newton-le-Willows as a failure, and yet there is some slight flaw which is of the greatest technical interest: and it is by such cases as these, if they were elucidated in a public enquiry, that information would no doubt be brought to light that could not fail to be of great benefit to the development of the science of sound reinforced concrete construction.

A NOTABLE BOOK ON REINFORCED CONCRETE.

As we go to press a copy of the third edition of Mr. Charles F. Marsh's standard work on " Reinforced Concrete " comes to hand, which now comprises some 650 pages of highly useful information, well illustrated with drawings, photographs, and diagrams.

If not in entire agreement with every argument or opinion put forward by Mr. Marsh, we cannot but congratulate him upon the general excellence of this splendid volume, which is encyclopædic in the information presented, and is a most useful reference book owing to the systematic manner in which the matter has been arranged. A volume of this description, which includes much in the form of mathematical data, speaks highly for the assiduity of the author, but at the same time the wider scope of the work and its increasing facts of interest speak well for the greater popularity of the subject, and the growing extent of the application of reinforced concrete construction.

If there is any criticism we should like to make as regards the volume it is that all illustrations and diagrams, no matter where placed, should have the title directly below them, and not only be given the reference figure.

CONSERVATISM REGARDING REINFORCED CONCRETE.

Certain paragraphs in Mr. Marsh's book, we think, require special reference at this stage. There is one as to the conservatism of engineers and architects in England. It reads as follows and should be borne in mind:—

> It is unfortunate that engineers and architects in England are so conservative, one might almost say prejudiced in their ideas, that many of them will not use this form of construction, even though their Continental and American *confrères* have proved to them so clearly its usefulness and economy, and above all, its safety; having shown that it may be employed with perfect confidence, and that by its use cheaper, lighter, and more durable structures may be erected than those built employing the old methods.
>
> Year by year the demand for cheap construction is increasing, and if we can replace iron, steel, masonry, etc., by reinforced concrete, reduce the thickness of retaining walls by the use of this material, and form of it light coverings to our service reservoirs, we shall lower the cost of construction and maintenance, and lose none of the stability thereby.
>
> Our bridges would be lighter, more graceful and cheaper, if instead of using brick or stone we employed reinforced concrete in suitable cases. What has been done by continental and American engineers can be done by English and we surely should take our place in the progress of the world, and not stand aside while others are not only experimenting with and obtaining valuable information about reinfoced concrete, but are also employing it for many important structures. Interest is certainly being aroused in this form of construction, but there still remains an unaccountable prejudice in some minds against its employment.

PRECAUTIONS AS TO REINFORCED CONCRETE.

Another paragraph which we should like to quote at this point is one as to the special precautions necessary in reinforced concrete work. The author says:—

> Great care and judgment are required in the selection and preparation of material and preparing of temporary work for the erection of reinforced concrete structures. The cement must be of the very best, finely ground and cool. The aggregate must be of the proper size for the different kinds of work, and should generally be perfectly clean, although it has been found that small percentages of clayey matter in a sand do not necessarily reduce the strength of the concrete or mortar, while, in some cases, it may be better to use an apparently dirty sand without washing. If there is any doubt as to the cleanness of the sand, careful tests should be made with it both washed and unwashed, lasting over as long a period as possible. The concrete when mixed should be moderately dry. The water should be quite clean, and the concrete thoroughly and carefully mixed and deposited.

SYSTEMS OF REINFORCED CONCRETE.

A notable paragraph of Mr. Marsh's is that dealing with the question of systems of reinforced concrete construction as distinct from what we would describe as special features. This reference should be particularly taken into consideration by the great public bodies and corporations having their own engineering departments, who should be able to prepare their own designs in reinforced concrete, and simply purchase from the specialist makers those materials or appliances which they particularly require, or adopt such parts of a system as may have proprietary rights for some special section of their work, such as a column or the like. Mr. Marsh's observations read thus:—

> Reinforced concrete construction is at present mainly in the hands of the patentees of the different systems, and of firms who have patented some detail of construction and made a speciality of this kind of work. It appears at first sight difficult to design and carry out a structure of this nature without infringing some of the many patents. It will be found, however, that the really valid patents are, generally speaking, those for some small detail, and that the main principles are not patented, and, in fact, are unpatentable. There are many ways of embedding iron or steel in concrete to obtain the results required, and if one form is patented, and the patent is valid, there are other forms which could be used just as well.

The above statement is one of the most valuable in Mr. Marsh's book.

PROPOSED ANTIQUATED OCEAN WHARVES FOR THE THAMES.

WHATEVER may be thought in shipping circles as to the desirability of the scheme for building deep-water wharves, 3,600 ft. long by 59 ft. wide, in Long Reach between Greenhithe and Erith, the fact that the promoters are seriously thinking, if they have not already determined the matter, of actually erecting these wharves in timber is most injudicious. Having regard to the fact, so frequently illustrated in these columns, that the life of timber is a short one, and that the maintenance expenditure is very high, the promoters should, if they have the interest of the proprietors at heart, reconsider the matter. Further, although two or three of the varieties of timber are very durable, even the least flammable will catch fire and burn fiercely after exposure to high temperatures.

It cannot be too strongly urged that there is an important difference between the "non-flammability" and the "fire-resistance" of structural materials, a point which seems to have escaped the notice of those who now contemplate the construction of the great wharves, transit sheds, and auxiliary works on the Thames. Surely steel, properly protected by concrete, or suitably-designed reinforced concrete, is indubitably a better form of construction. The slight additional capital expenditure necessitated is amply, we may say manifoldly, covered by the additional strength, durability, and saving in repair expenses and insurance premiums both for the buildings and their ever changing contents. It would indeed be regrettable if the Thames were again to provide an example of ultra-conservatism and wastefulness, and the proposal to adopt an admittedly inferior material for the erection of these ocean quays is quite inexplicable save on the grounds of ignorance or prejudice.

FICTITIOUS "PORTLAND" CEMENT.

We have had occasion, from time to time, to call attention to the great risk of using fictitious "Portland" cement, particularly so-called "Natural" cement from Belgium, and we have published in our preceding issue an important article on the subject. On this occasion we wish to give prominence to an important judgment in the Malta Civil Court, where it was proved that a Belgian company had been importing cement into Malta under a false British label. The case may serve as a warning to readers, both at home and in the Colonies.

THE MALTA CASE ON THE FICTITIOUS LABEL.

Regarding the case at Malta, Judge Roncali, sitting at the Civil Court on the 22nd October, 1906, gave judgment in an important trademark action instituted by a British company against an Antwerp firm, who had shipped from that port to Malta one hundred casks of cement labelled with the British company's trademark, although not manufactured by it. Moreover, the label bore a false announcement of the country of origin—that is to say, London had been substituted for the true city of origin—namely, *Antwerp*.

The British firm claimed the confiscation of the casks, which had been seized at the Custom House wharves, and also an injunction against the Belgian concern.

The Court allowed both claims, with costs.

The *Daily Malta Chronicle*, writing on the subject, stated that they had reason to believe that a good deal of foreign cement had been introduced into Malta under forged marks as British "Portland" cement; and the journal hopes that the judgment in question would have a salutary effect on that class of foreign merchants, who not only do great harm to British manufacturers, but are harmful to the public interests.

We certainly would call the particular attention of all merchants and makers of British cement to this finding.

THE "REINFORCED CONCRETE COMMITTEE."

The "Joint Reinforced Concrete Committee," inaugurated by the Royal Institute of British Architects, announces that it has divided its work among three sub-committees, dealing respectively with questions of materials, formulæ and fire.

We understand that the consultations of the sub-committees will shortly be in a sufficiently advanced stage to be considered by the full Committee, and a report may be expected in the spring.

The Committee is, we believe, much indebted to Sir Henry Tanner, I.S.O., for procuring the official printed matter of other countries, which has been of great value to their deliberations.

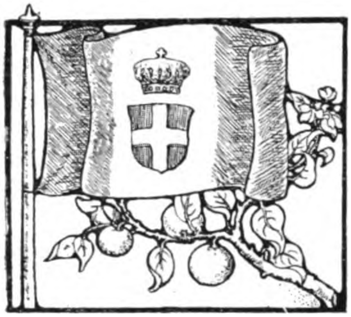
A "SPECIAL COMMISSION ON CONCRETE AGGREGATES."

We hear on excellent authority that an important "Special Commission on Concrete Aggregates" has been formed at the instance of the British Fire Prevention Committee from among its leading members and the representatives of the public bodies who are subscribers to the Committee.

The Commission is to report upon and define the aggregates suitable for concrete floors intended to be fire-resisting, having due regard to the question of strength, expansion, and the chemical constituents and changes of the aggregates.

The constitution of the Commission is not yet announced, but it is known that Sir William Preece, K.C.B., F.R.S. (Past President, Inst.C.E.), will be the Chairman, and that Mr. Matt. Garbutt, F.R.I.B.A., A.M.Inst.C.E., will be the Hon. Secretary; and, further, that the Commission will be an eminently representative one, particularly strong in civil engineers of great practical eminence and in public officials of high technical standing.

It is to be anticipated that the work undertaken by the Commission will be of that thorough character generally associated with the investigations of the British Fire Prevention Committee, and that its findings will have considerable international bearing on the subject of the fire-resistance of building materials generally, for the influence of the Committee reaches far beyond the confines of our Empire.



The Historical Evolution of Reinforced Concrete in Italy.

BY OLIVIERO NEGRI DI MONTENEGRO.

Bologna, Italy.

(FREE TRANSLATION.)

We have commented before in our pages upon the many uses to which cement is put in Italy, a country, indeed, where the uses of cement are being increasingly appreciated by the members of the technical professions and contractors alike. We are, therefore, publishing an article on "The Historical Evolution of Reinforced Concrete in Italy," which we would add to our historical series, in which we have already dealt with the development of the subject in France, Germany, and the United States. As the Italian literature on the subject is scarcely known in this country, special reference is made to existing writings.—ED.

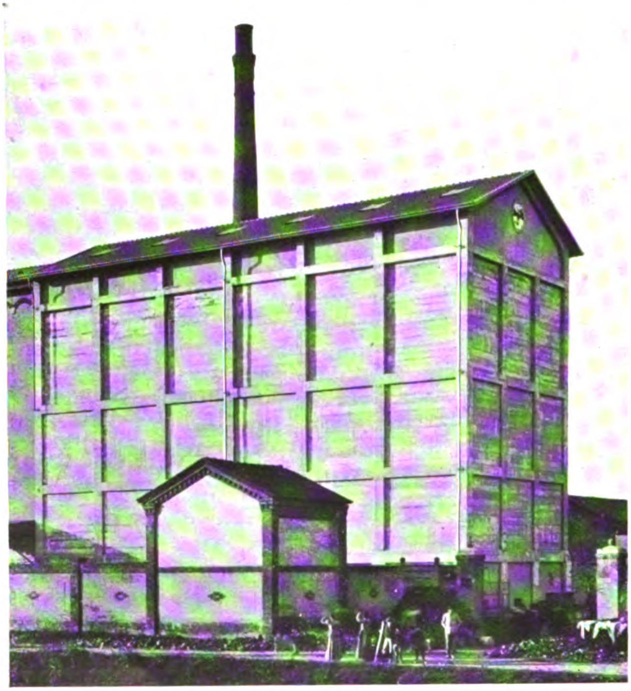
It was the Paris Exhibition of 1900, and especially the fine examples of reinforced concrete work executed on that occasion, which first introduced this form of building construction on a large scale into Italy.

In the year 1900 Prof. Canevazzi, of Bologna, published his book, "Sidero-cemento," in which he assumed the use of an element (concrete) without power to resist tensile stress, and Prof. Guidi, of Turin, also published his lectures on reinforced concrete construction. These works were all the more valuable as Italian engineers did not know at that time how to calculate for this form of construction, and even experienced firms were obliged to use empirical or almost empirical methods of calculation, and it is, therefore, quite intelligible that reinforced concrete met with a certain mistrust in Italy at first. It is solely to the perseverance of some of the persons concerned that we owe the fact that the new mode of construction has been at last welcomed and has steadily extended. It is especially Signor Porcheddu, Messrs. Hennebique, in Upper Italy, Prof. Muggia, in Emilia and Tuscany, Signor Chiera, in Latium, and Signor Martorelli, of Naples, in Southern Italy, who deserve the credit of having introduced reinforced concrete and of having made it trusted by engineers and builders. Their persistent and valuable efforts were not only directed to the undertaking of work such as floors, vaults, small bridges, etc., but also to making known and bringing forward the advantages of the new system by means of lectures, both at Technical Schools and before the Engineers' Associations.

Signor Canovetti, by the bye, had previously read an importnat paper on the subject in 1898 before the Technical Society of Emilia, at Bologna. In this connection we should further mention the address given to engineers in Florence by Prof. Muggia in 1898, and his "First Principles of Reinforced Concrete Construction," included in his lectures on Civil Engineering at the School of Applied Engineering at Bologna in 1899.

At that time General C. Caveglia had likewise busied himself with this subject with great success, publishing a valuable work and also important articles in the *Rivista d'Artigliera e Genio*, the *Ingegneria Industriale*, and the *Politecnico*. Signor Maciachini, the representative of the Walzer-Gérard patents, made known the method of calculation of Prof. Ritter, translating and publishing the original paper from the Swiss *Bau-Zeitung*.

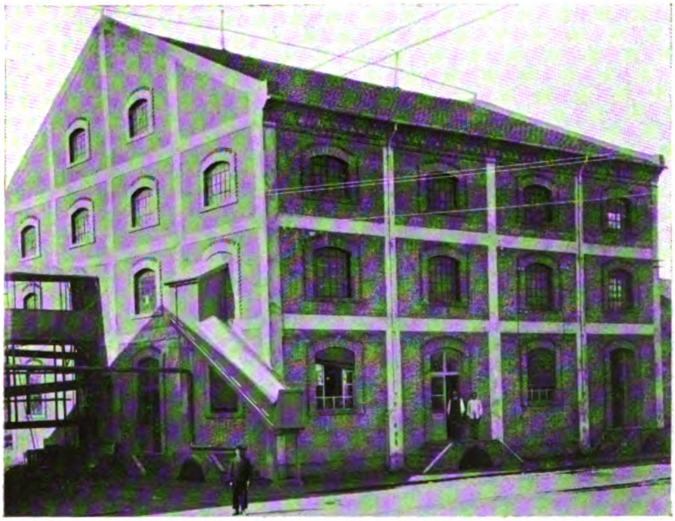
One of the earliest, perhaps the earliest Italian publication on the subject of reinforced concrete is that of Artorio, entitled "Cementi Italiani." In this work, which appeared in 1893, two articles from the *Industria* of 1888 and the *Revista d' Artiglieria e Genio* of 1890 are quoted, and these appear to be the first public accounts of armoured concrete, although, as we shall see later, patents for reinforced concrete construction had been granted even earlier by our Government. Artorio refers to such construction, however, as "little known in Italy," and, therefore, rarely employed.



SILOS FOR THE "ALTA ITALIA" GRAIN STORES AT FERRARA.
(*Messrs. Muggia, Bologna, Engineers*).

It was only in 1900 that the professors of the sciences dealing with construction at the Technical Schools found it necessary to deal *ex professo* with reinforced concrete. Prof. Camillo Guido, of the Royal School of Applied Engineering at Turin, delivered special lectures, which were then published in *L'Ingegneria Civile ed Industriale*. Prof. Silvio Canevazzi, of the Royal School of Applied Engineering at Bologna, then introduced the study of the strength of heterogeneous structures, and especially of reinforced concrete, into his course of instruction. These lectures were then collected to form a paper which was read before an association of engineers at Bologna, under the title of "Il Sidero-cemento," and published in the Proceedings of the association. Prof. Canevazzi had, however, even in 1895, referred to reinforced concrete construction in his lectures on bridges, and had shown its application to vaults.

Prof. Silvio Canevazzi was born at Modena in 1852, and graduated as a civil engineer at Milan in 1873. He was then appointed assistant in the Building Materials' Department of the Royal School of Applied Engineering at Rome, and entrusted with the course of instruction in that subject. In 1875 he studied at the Mining Academy of Liége, visited the principal mining districts, and worked for some time as an assistant on the Geological Survey in Cumberland. In 1877 he was appointed to the professorship of applied mechanics at the Royal School of Applied Engineering at Bologna, and he still continues the same course there, although he was appointed, in 1886, to the professorship of Bridge and Hydraulic Engineering.

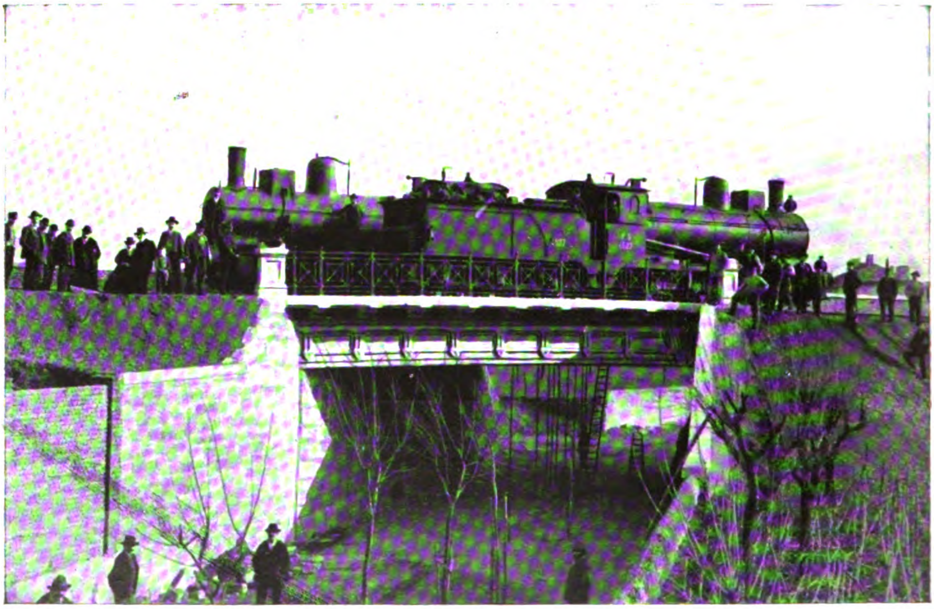

SUGAR WAREHOUSES OF SCHIAFFINO & CO., PONTELAGOSANO.
(*Messrs. Muggia, Bologna, Engineers*).

Prof. Canevazzi's most important publications relating to armoured concrete are:—

1. "Sidero-cemento": formulæ for the calculation of reinforced concrete structures. Bologna, 1901. Proceedings of the Association of Engineers.
2. "Appendice al Sidero-cemento," in which some original graphical methods for the calculation of armoured concrete are introduced, and the results obtained by employing the different hypotheses are compared. Bologna, 1902. Proceedings, etc.
3. "Ferro-cemento": formulæ for the elasticity and resistance of reinforced concrete structures. Turin, 1904. (See *Beton und Eisen*).
4. "Gli Sforzi latenti nel Cemento armato" (Latent stresses in armoured concrete). Revista tecnica emiliana, 1902.
5. The "General Specifications for Works in Reinforced Concrete," drawn up by Prof. Canevazzi and the late G. B. Mario (1904), has been treated in No. 2 of *Beton und Eisen* for 1904.

Camillo Guidi was born in Rome in 1853, where he graduated as a civil engineer in 1877. He remained there as an assistant at the technical school until 1882, when he was appointed Extraordinary Professor of Graphical Statics at the School of Engineering at Turin. In consequence of the death of Prof. G. Curioni, he was entrusted with the teaching of building construction at the same school, and in 1887 became Ordinary Professor of both subjects (graphical statics, elasticity and strength of materials, statics of buildings, theory of bridges, earth-pressures and retaining walls). Prof. Guidi is a member of the Royal Academy of Science of Turin. The titles of his most important published works on reinforced concrete are:—

1. "Experiments on the Elasticity and Resistance of Conglomerates of Concrete, Plain and Armoured"; Turin.
2. The second part of the above paper, in the same Transactions, 1901.
3. "Construction in Armoured Concrete." Lectures delivered in May, 1900. Turin, Bertolero, 1901.



GOVERNMENT RAILWAY BRIDGE, NEAR LECCO.
(*Messrs. Maciachini, Milan, Engineers*).

4. "The Advantages of a Municipal Control of Constructions in Armoured Concrete and the Mode of Exercising it." Proceedings of the Society of Engineers and Architects, Turin, 1903.
5. "Construction in Armoured Concrete." A Lecture delivered to the Society of Italian Engineers and Architects in Rome, 1903.
6. "Experimental Results obtained with Concrete Conglomerates, Plain and Armoured." Proc. Soc. Engineers, Turin, 1905.

Attilio Muggia is Professor at the School of Applied Engineering at Bologna, and also an eminent practical worker, who has been concerned with reinforced concrete for many years as Hennebique's representative. In 1897 he constructed the floor of the Civil Marriage Hall in the Municipal Buildings, the verandahs and columns of the Maccafen Palace at Bologna, and the floors of the Hospital at Portomaggiore; in the following year the floors of the Cattle Market, the hall and floors of the Eden Theatre, and a floor in an artillery-barracks, all in Bologna. In 1899 he erected three more important works: the tank for the Ferrara drainage system, with a pipe 2 metres in diameter, and the bridge over the Bandissolo. In 1900 Signor Muggia constructed the floors of the Etruria Sugar Factory at Cecina, Tuscany; floors of the Ferrara Sugar Factory at Ferrara; beams and floors to carry 4,000 kg./m.^{2} in the sugar warehouses of Schiaffino and Co., at Pontelagosano; the Ruggeri paper factory at Vignola, Modena; floors in the Military School of Modena; the mill at Porto Corsini, and many other buildings and structures, which are among the most important, not merely in Italy, but probably in Europe.

As we have already said, reinforced concrete was little known in Italy from either the theoretical or the practical side before 1900, and its application was comparatively limited, although it must naturally not be assumed that important works were not executed. It is certain that from 1900 onwards reinforced concrete has come more and more into use, and is, at the present day, quite commonly employed in Italy. Besides its great use for floors and in dwelling-houses, it is applied to the construction of road and railway bridges, foundations, reservoirs, etc. Amongst recent erections Italy can show important and artistic structures in armoured concrete. Of these the most remarkable are:—

The bridge over the Dora Riparia at Turin (engineer, Porcheddu).

The bridge at Piombone, the first bridge constructed in Italy with continuous girders (engineer, Muggia, 1900).

The bridge over the Tagliamento at Pinzano, Udine, 1903, a bold and striking work of the engineer Vacchelli, of Rome. It is 194 metres long, 5 metres wide, and consists of 3 large arches of 50 metres chord (see *Beton u. Eisen*).

The silos for the "Alta Italia" grain stores at Ferrara, completely constructed in armoured concrete, and holding 36,000 metre-centners of wheat (engineer, Muggia, 1904).

The new bridge over the Reno between Alberino and Codifiume (provinces of Bologna and Ferrara), designed and constructed by the Bolognese firm of Marchello.

The arched bridge over the Nera at Papigno (Umbria), was designed by Signor Vacchelli, and constructed at the beginning of 1905 by the firm of Odorico, of Milan.

The reservoir at Castello Sfozzesio, Milan (March, 1905).

The viaduct at Fabriano (Ancona), constructed in 1905 by the firm of Marchello.

The water tower of S. Salvi, Florence, by Prof. Muggia (June, 1905).

The bridge over the Rino (1905).

The reservoir at Torre Vittoria, Messina (1905).

Reinforced concrete factory chimneys in 1904 and 1905.

The reinforced concrete railway bridge on straight girders over the Moria (1906).

The bridge over the Santerno, by Prof. Muggia (1906).

It should also be remembered that during the current year 300,000 reinforced concrete railway sleepers have been constructed.

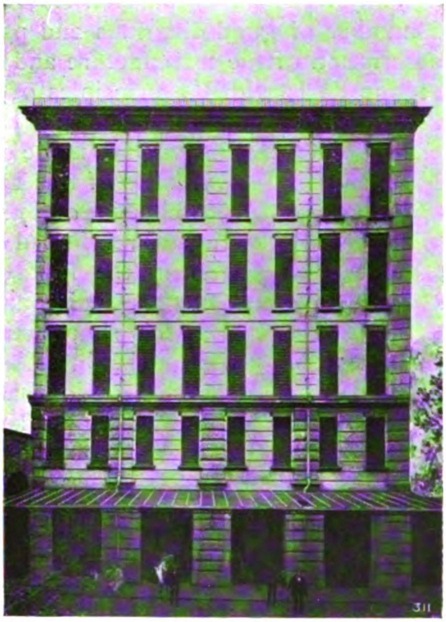
Of works at present in progress, another of Prof. Muggia's calls for attention, viz., the bridge over the Magia at Caprigliola Albiano, Massa Carrara, the largest bridge yet constructed in reinforced concrete. It is 258 metres long without the abutments, and consists of 5 arches, each of 51.5 metres span. A temporary bridge used in its construction was also built in reinforced concrete.

For some years past a number of able and enterprising men, in addition to those already mentioned, have concerned themselves in Italy with reinforced concrete, and their names and work have been frequently referred to in both the Italian and foreign technical press.

Signor Cosimo Canovetti, of Milan, is another engineer whose name must not be omitted, and was among the first to devote himself to the study of reinforced concrete. He was one of the most brilliant students of the School of Engineering in Paris, and often communicated his results to the public. As director of the municipal technical department of Brescia, he has designed and caused to be constructed a number of reinforced concrete cisterns for the town laundries; these cisterns had a capacity of 2,000 to 5,000 litres, and the first were constructed as far back as 1889. One of the most important, which was described and illustrated in the

ITALIAN REINFORCED CONCRETE MILL (INTERIOR VIEW).
(*Messrs. Maciachini, Milan, Engineers*).

Politecnica, and soon after in the *Illustrazione Italiana*, is that of the Via Sa. Francesca Romana. This cistern holds 3,000 litres and has flat sides, one of which is exposed to extremes of temperature. The sides are 5 cm. thick, and of Portland cement concrete. Canovetti has always strongly advocated the use of Portland cement only for water reservoirs. He also made experiments on the permeability of sand mortars to water, and found that the permeability depended more on the quantity of water used in mixing the mortar than on the proportions of the cement-sand mixture. A detailed description of these works and experiments is to be found in Canovetti's papers: "The New Public Washhouses of the City of Brescia" (*Ingegneria Sanitoria*, 4. No. 9, 1893) and "Armoured Concrete" (*Monitore Tecnico*, 1898).



NEW REINFORCED CONCRETE WAREHOUSE FOR THE MILAN MONT DE PIÉTÉ.

As to the vexed question of so-called patents as far as Italy is concerned, it would appear that the first Italian patent for reinforced concrete construction was taken out by Angelo Lanzoni, of Pavia, in March, 1883. This was followed in 1895 by a patent for the construction of doors, windows, etc., of reinforced cement, especially for cellars, stables and warehouses. Monier's patent was only taken out in Italy in July, 1883; the priority in Italy, therefore, rests with the Italian inventor. Lanzoni has never advertised his invention largely, but those who have made use of these doors, windows, etc., and have tested them thoroughly, regard them as entirely justifying the claims made for them. The list of users shows not only the growth in popularity of this kind of construction, but also the fact that those who have once used the system return to it repeatedly, which is the best evidence of its advantages. As proprietor of the firm of Lanzoni, Galli and Co., it should be remarked that Signor Lanzoni had so early as 1878 made some special applications of steel in cement, but no patents were applied for at the time.

Among the most prominent engineers in reinforced concrete construction is undoubtedly Signor A. Maciachini, of Milan. He has undertaken all kinds of armoured concrete work, and articles on constructions carried out by him have appeared on several occasions in *Beton und Eisen*. He is the owner of several patents, including that of Walzer-Gérard (of Bâle) and Maciachini, and a patent of his own for a new kind of "Béton fretté."

In December, 1905, he published, in Milan, an interesting account of "Hollow Concrete Block Floors" (Jens G. F. Lund's system, Christiania, Norway). This account consists of several sections, and is illustrated with a number of good diagrams and photographs. The author begins with a description of the manufacture and application of the materials, the second section deals with the principles of execution, and the third treats fully of the calculation of dimensions. The succeeding sections contain valuable experimental results, and the mode of erection of Lund's reinforced concrete blocks and the advantages of this system occupy the last third of the work.

Signor G. A. Porcheddu, of Turin, has also been concerned very largely with the construction of reinforced concrete works.

Other engineers of the first rank who have carried out reinforced concrete work in Italy are F. Leonardi and Mario Baroni, of Milan.

We cannot close this short article on armoured concrete in Italy without expressing our indebtedness to Dr. Morbelli, director of the Italian journal, *Il Cemento*. This journal, although only in its third year, has already attained to an important place in Italian technical literature, and has had considerable influence on the development of reinforced concrete in Italy, for it deals in a most practical and at the same time scientific manner with the subject here under consideration.

REINFORCED CONCRETE HOSPITAL BUILDINGS AT RAPALLO.
(Messrs. Maciachini, Milan, Engineers).

Reinforced Concrete Bridges.

IV.

By W. NOBLE TWELVETREES, M.I.Mech.E.

In no department of constructional engineering has reinforced concrete been found of greater service than in that of bridge work, and although Great Britain can show but few examples of reinforced concrete bridges, they can be counted by hundreds on the continent of Europe and in the United States. In the present series of articles the author summarises the features of the most useful types of reinforced concrete bridges with the view of demonstrating the many forms available for the British designer.—ED.

BRIDGE OVER THE ISAR, NEAR GRÜNWALD, BAVARIA.

At the end of the able article by Mr. Kohlmorgen on "Reinforced Concrete in Germany," which appeared in CONCRETE AND CONSTRUCTIONAL ENGINEERING for November, there was reproduced a general view of this fine bridge, built by the firm of Wayss and Freytag, of Neustadt, for the District Council of Munich. For the convenience of readers the same view is repeated in *Fig.* 38.

The work comprises two three-hinged arches of 70 metres clear span, and two girder approaches—one 47 metres long and the other 21 metres long—the total length being about 215 metres and the total width 9.2 metres, which includes a roadway 5 metres wide and two footpaths each 1.5 metres wide.

Fig. 34 is an elevation, partly in section, by which the general character of the design is made clear. Each span comprises a wide arch rib reinforced and hinged as shown in the detail drawing, *Fig.* 36. Upon the rib there are five rows each of five vertical struts forming open spandrels. The struts are reinforced as illustrated in *Fig.* 36, and are connected by longitudinal and transverse beams and a platform slab of which a section will be found in *Fig.* 37, giving further particulars of the reinforcement in the platform slab and beams. *Fig.* 39 shows a photograph of the bridge in course of construction, and in *Fig.* 35 will be found some interesting details of the centering.

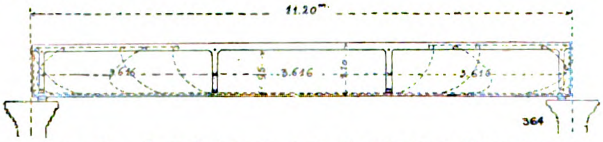


FIG. 33. SANT' AGATA AND COTIGNOLA BRIDGES: Longitudinal Section of Main Girder.

Construction of the bridge was commenced in the autumn of 1903 and completed in August, 1904, the total cost being about £13,000.

TWO GIRDER BRIDGES IN ITALY.

In April, 1898, the Ravenna Provincial Council decided to build two new bridges over the rivers Santerno and Senio, at Sant'

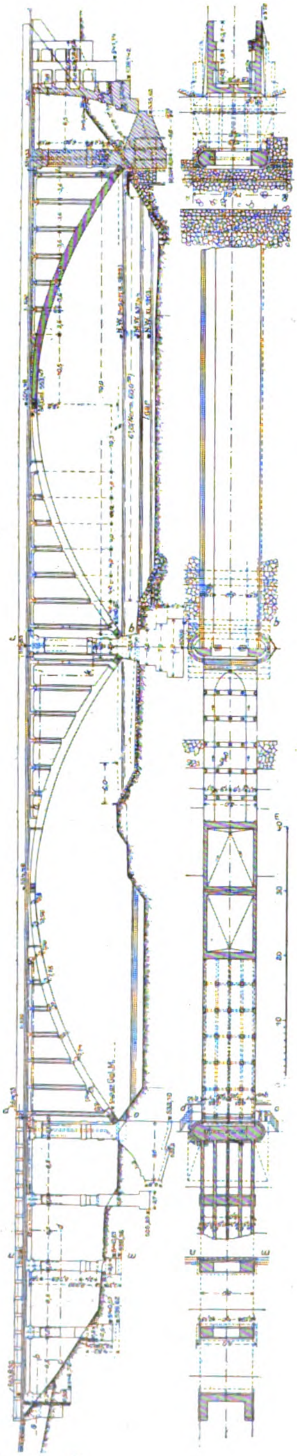


FIG. 34. GRÜNWALD BRIDGE: ELEVATION PARTLY IN SECTION.

Agata and Cotignola. As it was found that the amount that the Council were willing to pay would be quite insufficient to cover the cost of steel structures, a technical commission was appointed to consider the merits and relative cost of various types of reinforced concrete bridges, with the result that the Council ultimately accepted an offer, based on the Bianchi system, to build the two bridges for about £4,500.

Figs. 40 and 41 are elevations of the Sant' Agata and Cotignola bridges, which are of similar design, although the lengths are 58.35 metres and 38.36 metres respectively.

The Sant' Agata bridge over the river Santerno includes five girder spans of 21.94 metres clear, supported by reinforced concrete piers each founded on 27 piles driven to the depth of 7.65 metres below the river bed, the abutments being founded on piles of shorter length, as indicated in *Fig.* 40.

The Cotignola bridge over the river Senio comprises three reinforced concrete girder spans of 10.65 metres clear, supported by two reinforced concrete piers with piled foundations extending 7 metres below the bed of the river, with shorter piles for the abutment foundations (*Fig.* 41).

Each bridge has a width of 6.30 metres between parapets, and simply provides accommodation for a roadway.

Fig. 42 is a section through one of the piers in the Sant' Agata bridge, giving details of the reinforcement, and *Fig.* 43 contains similar particulars relative to the Cotignola bridge.

The distinctive feature of the Bianchi system is to be found in the curved bars shown in the upper transverse member of each pier in *Figs.* 42 and 43, and in the longitudinal section of a main girder in *Fig.* 33.

Both of these bridges are of simple and inexpensive character, and by their construction the Provincial Council of Ravenna

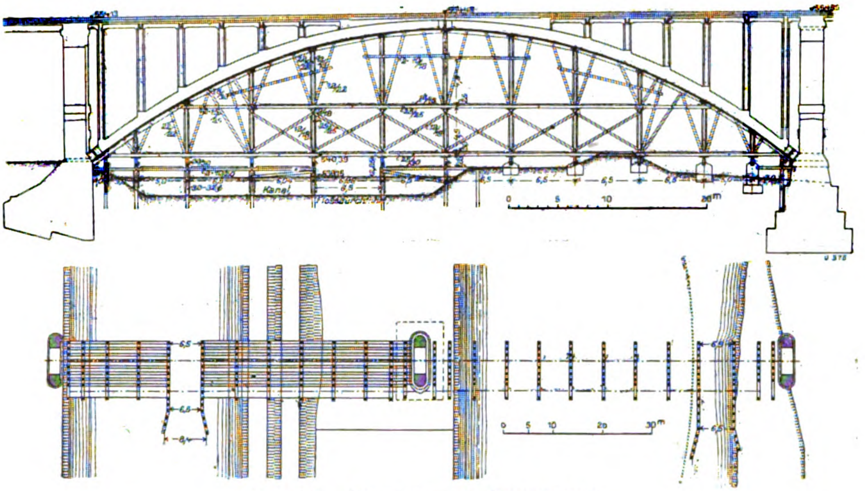


FIG. 35. DETAILS OF CENTERING.

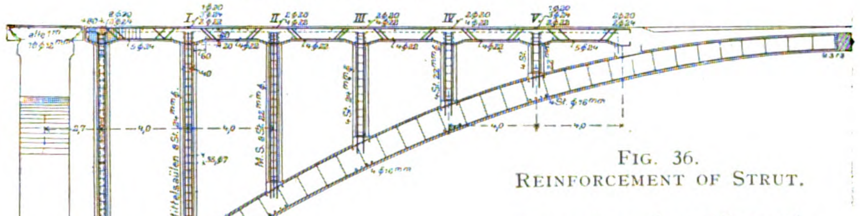


FIG. 36. REINFORCEMENT OF STRUT.

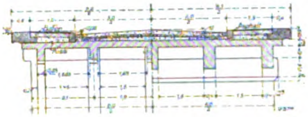


FIG. 37. SECTION OF BEAMS AND PLATFORM SLAB.

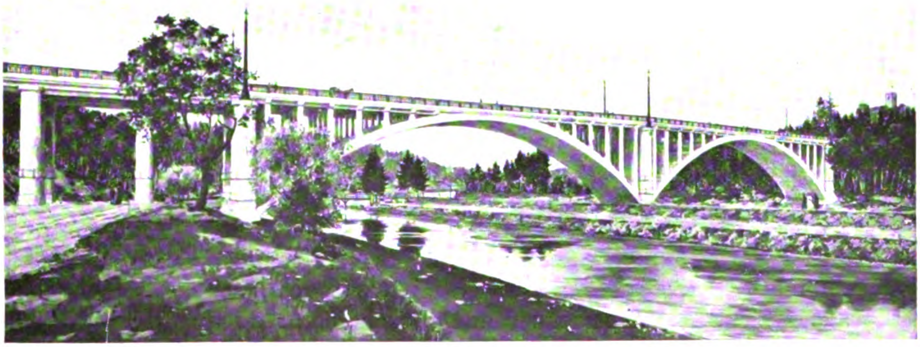


FIG. 38. GENERAL VIEW OF THE BRIDGE.

THE BRIDGE OVER THE ISAR, NEAR GRÜNWALD.

has solved, in an economical and permanent manner, the important problem of providing convenient means of communication across the two rivers.

THE AVRANCHE VIADUCT.

A viaduct embodying the same principles as those exemplified in the Guillia Viaduct and the Pougastel Bridge (see p. 347 *ante*) is now being built at Avranche in Brittany (see *Fig.* 44), in which three types of construction are represented: (1) A bowstring girder span of 72 ft.; (2) two parallel latticed girder spans of 34 ft.; and (3) an arch span of 115 ft. 6 in., the total length of the bridge being 256 ft. between abutments.

Except in respect of dimensions, the bowstring girder will constitute a reproduction of the Pont d'Ivry, which was subjected to severe tests in the presence of numerous French and other engineers with complete success. The calculation of the dimensions of this girder is very simple, and does not call for detailed comment.

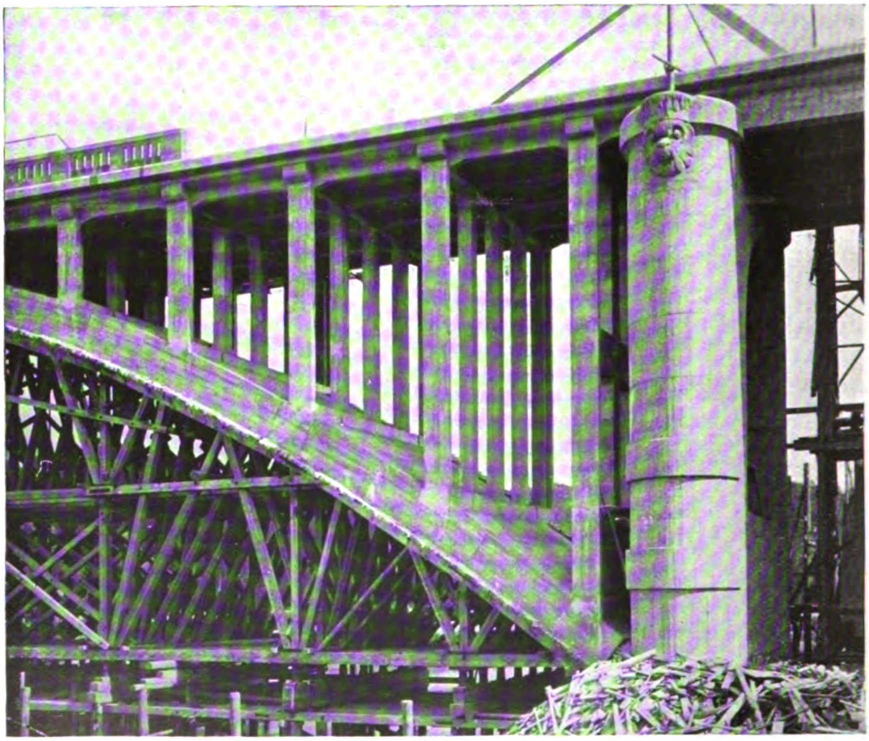


FIG. 39. GRÜNWALD BRIDGE: VIEW DURING CONSTRUCTION.

With regard to the arch, it should be remarked that when a rolling load comes upon the span the rails of the permanent way are affected by the transverse strains experienced in the arch, and consequently add to the resistance of the construction. It was necessary to determine the laws of this association, and to find means of calculating the effects in a simple manner. M. Considère discussed this point in a recent issue of the *Annales des Ponts et Chaussées*, wherein he demonstrated the importance of taking into account the aid given by the track in railway arches of reinforced concrete. He also points out the facts that designers who employ reinforced concrete do not always allow for the strains resulting from shrinkage during the setting process, and the effects of temperature variations, and that they are also apt to overlook the effects following the application of powerful brakes.

To indicate the importance of these causes of strain it is sufficient to point out that upon a total bending moment of 121 ton-metres, more than 76 ton-metres are due to shrinkage, temperature variations, permanent dead load and braking—

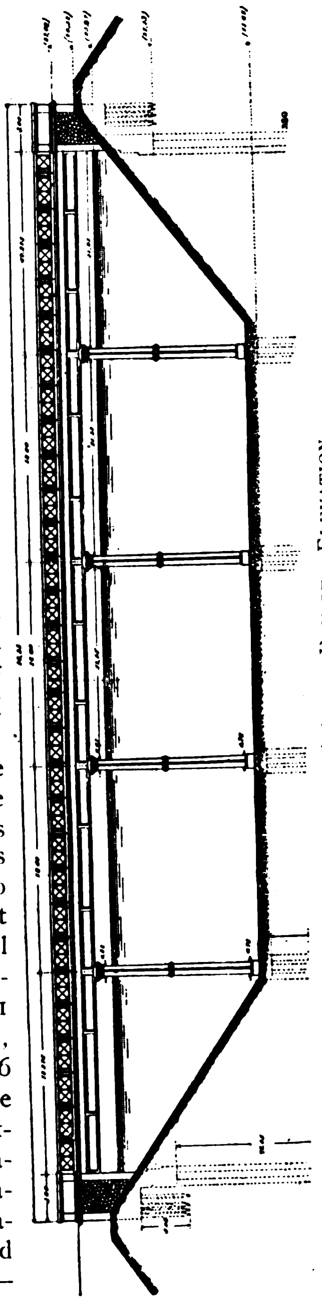


Fig. 40. Sant' Agata Bridge: Elevation.

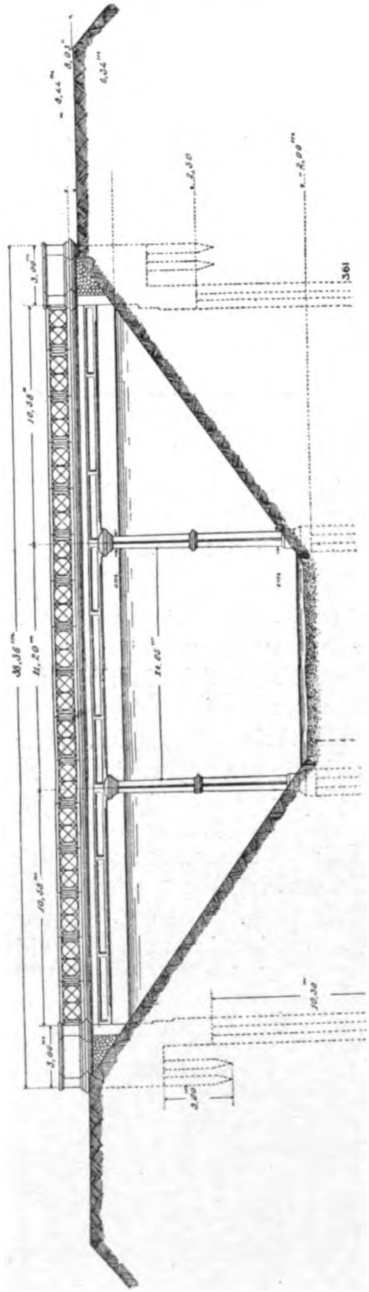


Fig. 41. Cotignola Bridge: Elevation.

all these being causes which have not usually been properly considered in connection with reinforced concrete works, although they are not neglected by the designers of metallic structures.

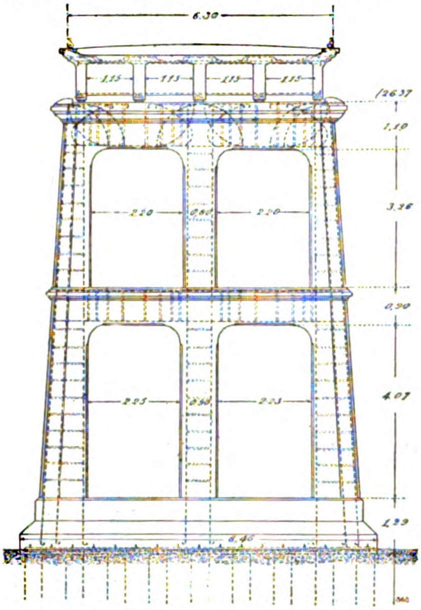


FIG. 42. SANT' AGATA BRIDGE.

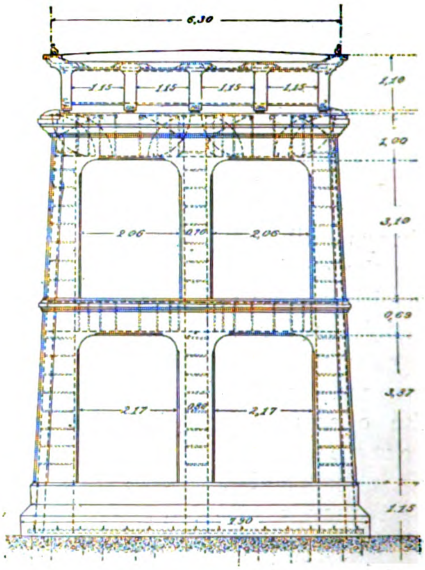


FIG. 43. COTIGNOLA BRIDGE.

It may be remarked that in the case of the Avranche Viaduct the railway line will be laid upon sleepers exactly as in open country, and that in the event of derailment the trains will run upon the ballast and thus expend their momentum. The cross girders carrying the permanent way have been so calculated that they will not be hurt should a train be derailed.

THE POLLASKY BRIDGE, CALIFORNIA.

This bridge across the San Joaquin River, in California, comprises ten 75 ft. arch spans, and at each end the abutments are carried back as wing walls, making the total length 780 ft., while the width inside the spandrel walls is 18 ft. The arches, piers, and abutments form one monolithic mass, but expansion joints are provided for the spandrel walls over each pier.

The reinforcement consists exclusively of Patent Indented Bars. Six sets of centering were used for the bridge, being moved from span to span as work progressed (see *Fig.* 46).

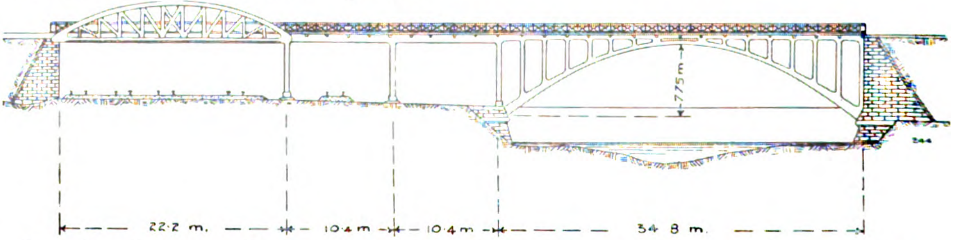


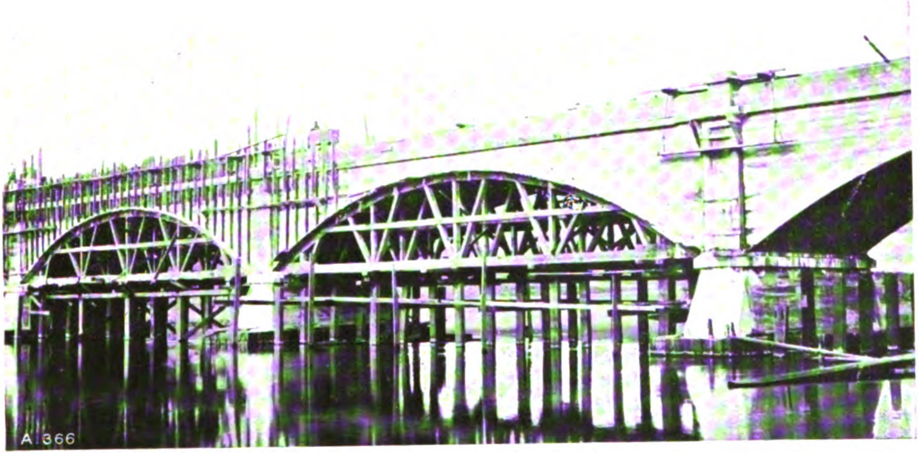
FIG. 44. AVRANCHE VIADUCT: DRAWING SHOWING THREE TYPES OF CONSTRUCTION.

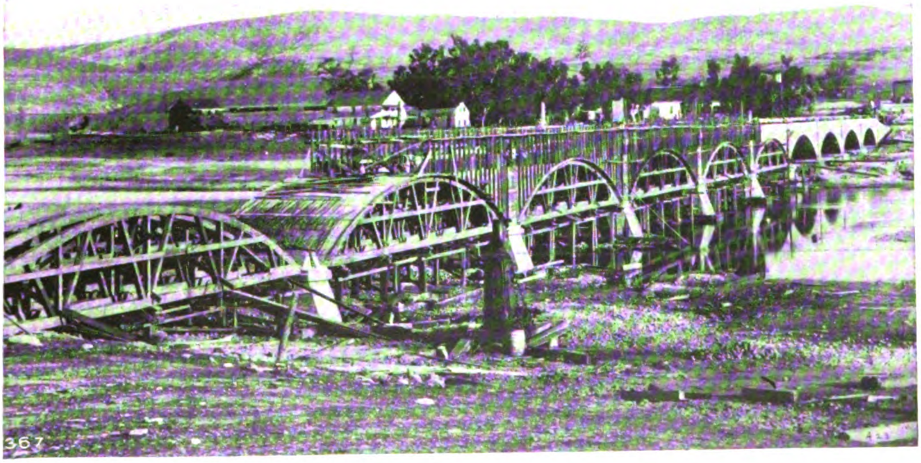
Tracks laid from end to end along the bridge, as illustrated in *Fig.* 45, were used for delivering the spandrel filling, which consisted of gravel raised from the river bed by means of bucket elevators.

The bridge was designed by Mr. John B. Leonard, who is the engineer for the Indented Bar Company in the district of San Francisco, and was built by the Pacific Construction Company of the same city.

A DOUBLE TRACK RAILWAY BRIDGE IN ILLINOIS.

This structure is interesting as another example of reinforced concrete railway bridges, and illustrating the Indented Bar system of construction.

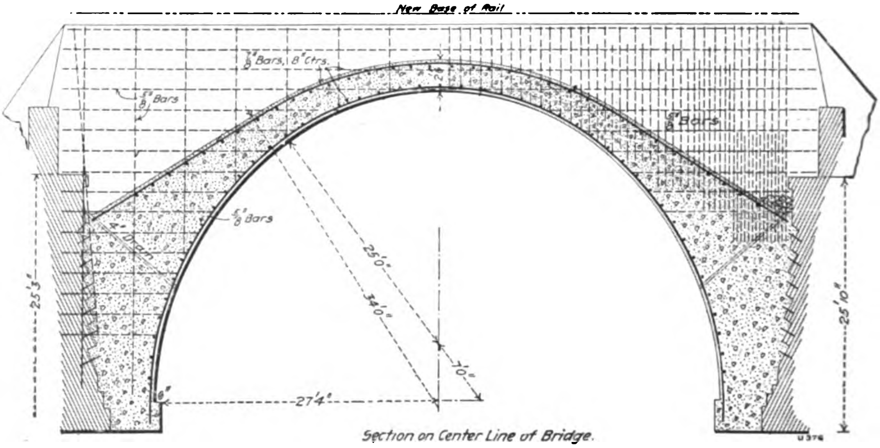


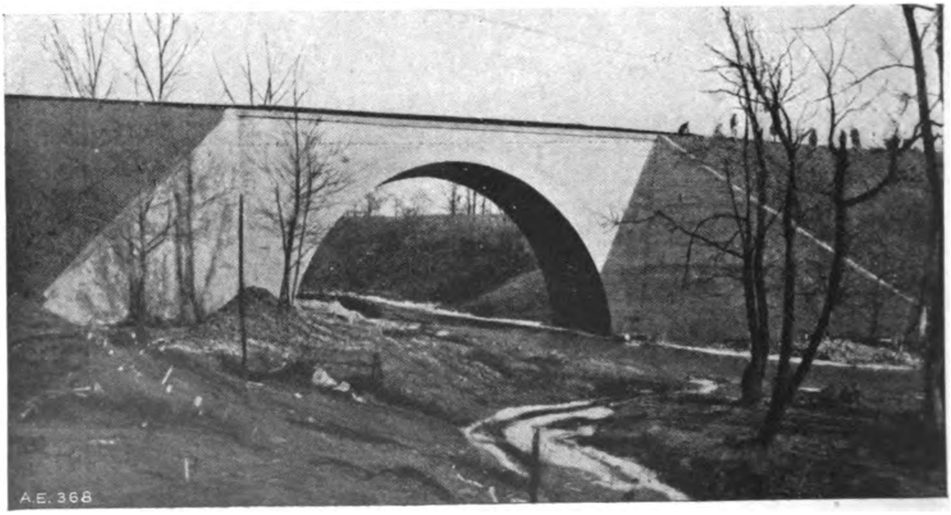


FIGS. 45 & 46. POLLASKY BRIDGE.

Fig. 48 is a view of the completed work, which is situated on Stoney Creek, a short distance to the north of Danville, Illinois, and has replaced a plate girder bridge. The arch is parabolic, with the clear span of 54 ft. 8 in., the thickness of 2 ft. 6 in. at the crown, the overall width of 32 ft. 6 in.

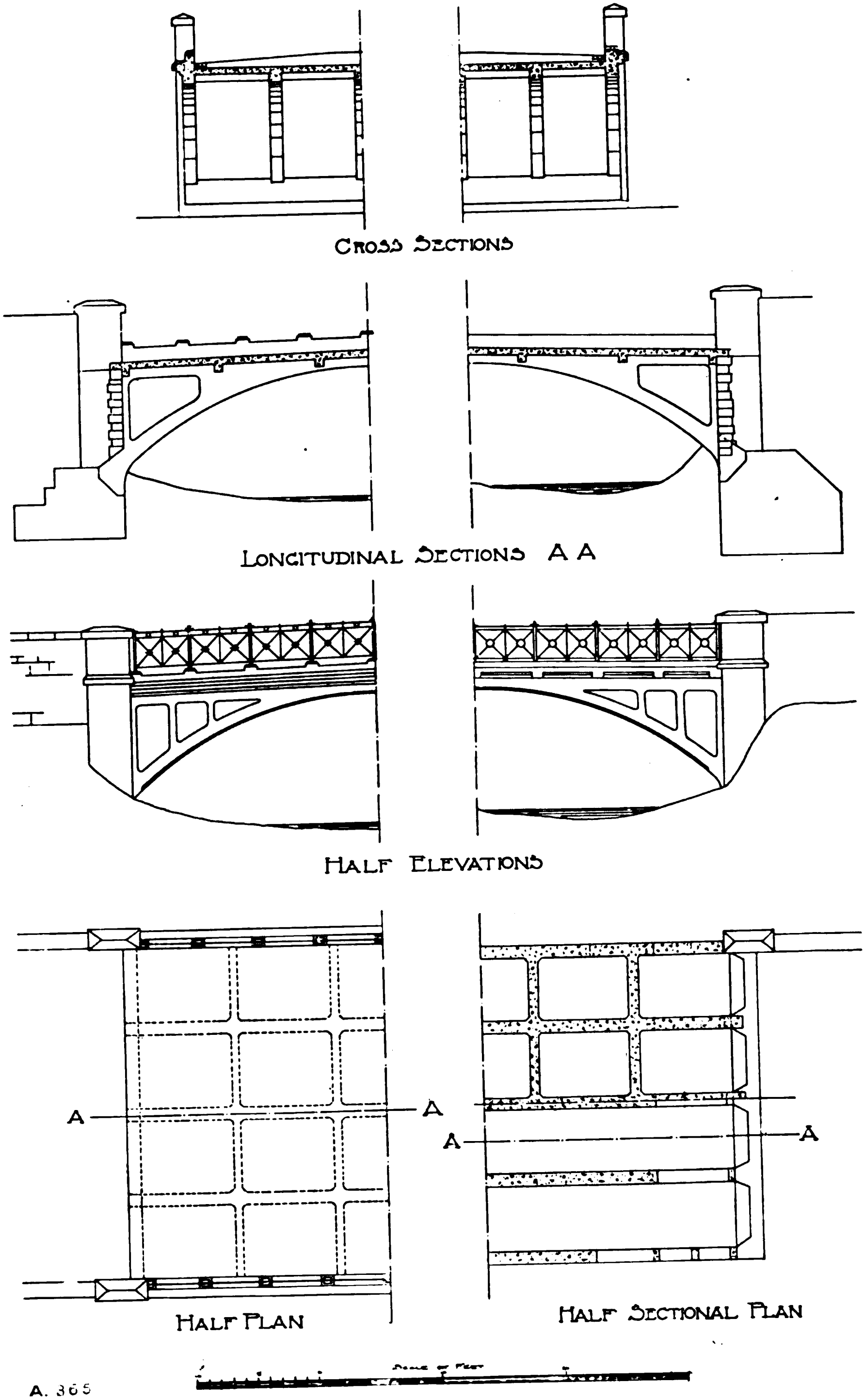
One specially interesting feature of the work is to be found in the wing walls. The old wing walls were reinforced by the addition of concrete to the thickness of 4 ft. on each face, carried up from the foundations to a suitable height, this concrete being tied to the old masonry by steel dowels. The general system of reinforcement is shown in detail in *Fig.* 47.





FIGS. 47 AND 48. STONEY CREEK BRIDGE.

The bridge was designed by Mr. T. L. Condron under the direction of Mr. W. S. Dawley, chief engineer to the Chicago and Eastern Illinois Railroad.



A. 365

LILBURN BRIDGE. FIG. 49. LUCKER BRIDGE.

THE LILBURN AND LUCKER BRIDGES, NORTHUMBERLAND.

These two bridges, identical in all respects save that some dimensions and form of the abutments differ slightly, were designed for the Northumberland County Council by Mr. Harry W. Taylor, A.M.Inst.C.E., in accordance with the Kahn system of reinforced concrete.

They take the place of two masonry bridges, one over the Lilburn burn and the other over the Warren burn, that were washed away in the great flood of May 19th, 1906. *Fig.* 53 is a view of Lilburn bridge after the flood, showing the masonry arch and walls completely destroyed, with the coping, which had been set in cement, still remaining in place, thus demonstrating the value of Portland cement in constructional engineering.

Fig. 49 contains half plans, sections, and elevations of the two bridges. The abutments in each case are of mass concrete, only the superstructure being in reinforced concrete. No trouble was encountered with the foundations of Lilburn bridge, but a considerable amount of piling was necessary for supporting those of Lucker bridge.

The bridges were designed to carry a rolling load of 30 tons represented by two 15-ton traction engines passing together side by side or tandem over each bridge.

THE CHARLEY CREEK BRIDGE, INDIANA.

The Charley Creek bridge at Wabash, Indiana, is built entirely of reinforced concrete on the Kahn system. It is 240 ft. long, and comprises two parabolic arches of 75 ft. clear span, and 18 ft. rise, the roadway being 32 ft. wide.

The arch ring is designed in accordance with the method of calculation advised by the late Professor Greene, of the University of Michigan. *Fig.* 51 is a section of one arch, the thickness of which is 1 ft. 6 in. at the crown and 3 ft. 4 in. at the haunches. The central pier is 6 ft. wide. The arch is reinforced entirely with Kahn bars. Those in the intrados measure 1 in. by 3 in. by 30 ft. long at the haunches, and others of the same size over the entire arch. In the extrados the bars measure 1 in. by 3 in. by 40 ft. long over the crown, and others of the same size over the entire arch ring. All these bars are laid in rows 2 ft. apart centre to centre.

A number of ¾-in. diameter round rods are placed transversely to the axis of the arch to resist temperature stresses. The spandrel walls were designed as vertical cantilever slabs, and are reinforced with Kahn bars.

The concrete in the arch ring was mixed in the proportion of 1 part cement, 2 parts sand, and 4 parts broken stone. In the spandrel walls and foundations, the proportions were 1 part cement, 2½ parts sand, and 5 parts broken stone.

To make both arches continuous as far as possible 1-in. by 3-in. Kahn bars were placed at the junction of the two arch rings on the centre pier.

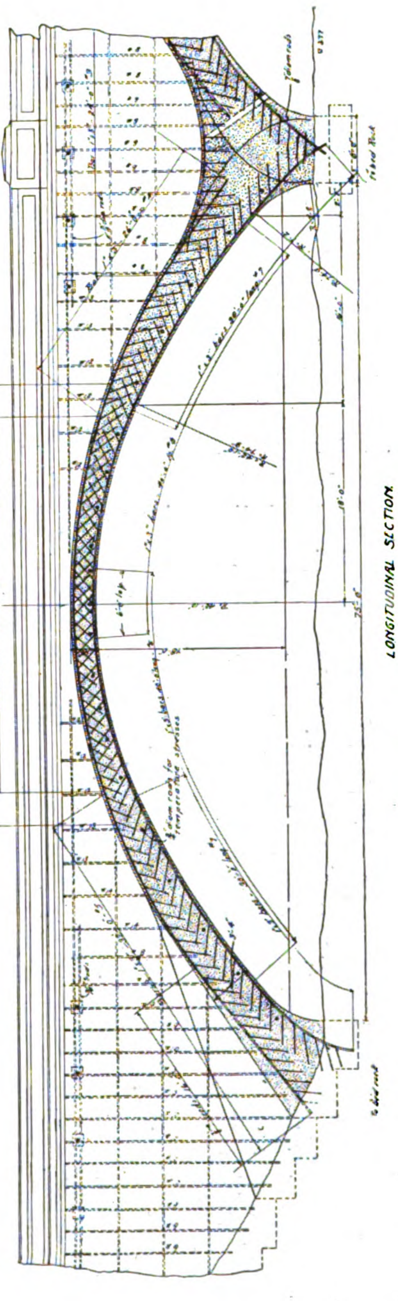


FIG. 51. CHARLEY CREEK BRIDGE.

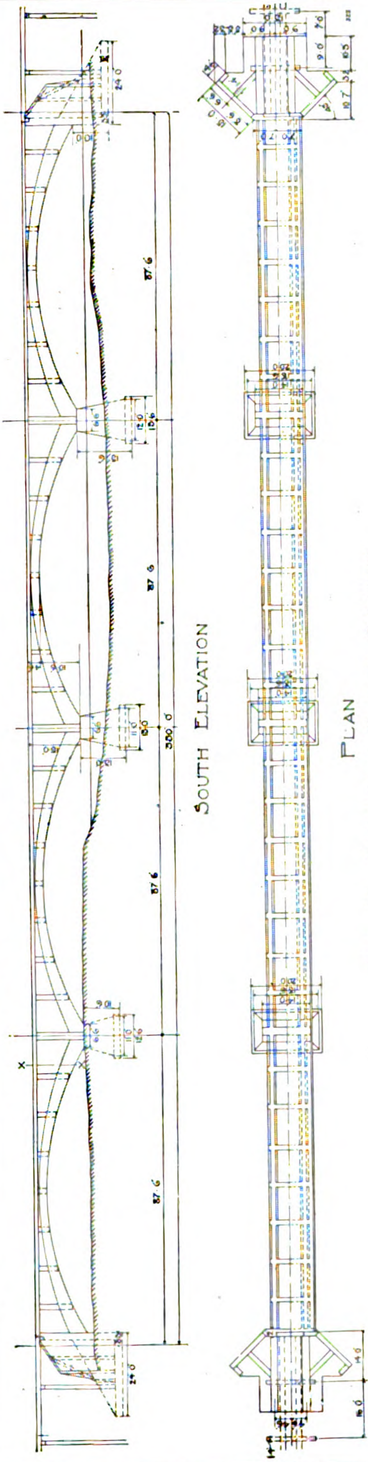


FIG. 52, BELVIDERE BRIDGE, ILLINOIS.

THE BELVIDERE BRIDGE, ILLINOIS.

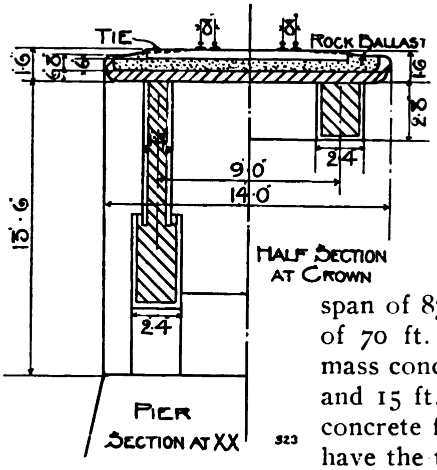


FIG. 52. BELVIDERE BRIDGE, ILLINOIS.

The first bridge designed in the United States in accordance with the most recent Strauss patent is the structure completed for the Elgin and Belvidere Railroad Company, over the Kishwaukee River, near Belvidere, in Illinois. *Fig.* 50 contains an elevation and plan of the bridge, which is 350 ft. long between abutments, and includes four segmental arches, each with the span of 87 ft. 6 in. centre to centre, and the rise of 70 ft. 6 in. The three river piers, built of mass concrete, are respectively 10 ft. 6 in., 13 ft., and 15 ft. 6 in. in height, and are founded upon concrete foundation slabs, 2 ft. thick. Two piers have the transverse dimensions of 11 ft. by 16 ft. at the base, and the third those of 12 ft. by 18 ft. 6 in., all three tapering to give the uniform cross-sectional dimensions of 6 ft. 6 in. by 14 ft. at the springing level of the arches.

As illustrated in *Fig.* 52, each arch comprises two main ribs, 2 ft. 4 in. wide by about 4 ft. 7 in. deep at the haunches, and 3 ft. deep at the crown, these ribs being spaced 9 ft. apart, centre to centre. Each rib carries a spandrel wall 1 ft. 4 in. thick, between which, and also between the ribs, transverse diaphragm walls 1 ft. 4 in. thick are built at intervals of nearly 11 ft. apart. The platform slab is 14 ft. wide over all by 5 in. thick, being moulded with a curb 8 in. high at each side, so as to constitute a trough for the rock ballast upon which the railway track is laid.

The bridge was designed in such manner as to render unnecessary the use of centering. The arch ribs were built in trough-shaped moulds of reinforced concrete, divided into seventeen sections for each rib. These sectional moulds, made without ends, were 3 ft. deep for the crown, 4 ft. 7 in. deep for the haunches, and of graduated depth for the intermediate portions of the ribs. Their sides were 3 in. thick and the bottom 4 in. thick. After the moulds had been erected in arched form between the abutments on the site of the bridge, the cores or arch ribs proper were moulded in them. Each of the sectional moulds was reinforced by a network of $\frac{3}{8}$ in. diameter steel bars placed 8 in. apart longitudinally, and 12 in. apart transversely. Similar moulds were made for the 32 diaphragm walls in the four arches.

The sectional moulds of the arch ribs, and those for the diaphragm walls connecting the latter, were themselves formed in moulds of sheet steel stiffened by channel bars, and kept in alignment by angle bars so arranged that each mould could be taken down and re-erected without trouble or delay. As the four arches of the bridge are symmetrical and of uniform dimensions, only nine different sizes of sectional steel moulds were required for the ribs, and one steel mould for the diaphragm walls.

When all the reinforced concrete voussoir and diaphragm moulds had been made they were numbered and stored near the site in readiness for use. For the purposes of erection two longitudinal rows of piles were driven on either side of the space to be occupied by the bridge, and were capped with transverse planks on top of which stringers were laid to carry the rails for a travelling crane, spanning the site of the arches.

The sectional moulds were framed together in pairs at the proper distance apart one from the other by means of timber and steel bolts. The erection of the arch ribs was commenced simultaneously from each springing, the first two pairs of sectional moulds being supported at one end on the skew-backs and at the other end by steel bars suspended from frames—one on the abutment and anchored to the bridge approach, and the other on the pier at the opposite end of the arch and anchored back to the second pier. The second two pairs of sectional moulds were next brought into position and supported at the inner end by means of steel dowels or timber blocks upon the two sections of the first pairs and at the outer end by second sets of steel bars from the erection frames. In a similar manner the other sections were assembled until the key section was inserted, and the arch then became self-supporting. The sectional moulds for all four arches of the bridge, and those for the transverse diaphragm walls, were completely erected before any concrete was deposited.

When the sectional moulds for the ribs were all erected, and the reinforcement had been laid in them, concrete was deposited to form the arch ribs and the diaphragm walls, the spandrels and the platform slab being formed in timber moulds of the ordinary type.

The reinforcement in the arch ribs consist of ⅞ in. diameter steel bars in the intrados and the extrados, with radial bars for resisting shearing stress. The longitudinal bars are connected by 3 ft. overlaps and are anchored into the foundations. In the spandrel walls the reinforcement consists of ⅜ in. diameter bars laid horizontally and vertically, and spaced 12 in. apart, centre to centre. The platform slab is reinforced by ½ in. diameter bars, spaced 5½ in. apart, centre to centre, disposed transversely near the lower surface of the slab, every alternate bar being bent up so as to constitute reinforcement for the side curbs. The floor contains ⅜ in. diameter bars, disposed longitudinally and wired to the transverse bars.

Although the erection plant required for building bridges in this manner is more costly than the usual centering, it is claimed that by its aid construction can be conducted rapidly at very low cost, and further, that the steel moulds and other plant, having once been provided, can be used repeatedly for similar work.

The Belvidere Bridge was designed and built by the Strauss Bascule and Concrete Bridge Company, of Chicago, the execution of the work being under the supervision of the engineer to the Arnold Company, who are the general contractors for the construction of the Elgin Belvidere Railroad.

CONCLUSION.

In the series of articles now brought to a close, the writer has given examples of different types of bridge construction designed in accordance with some of the leading systems of reinforced concrete. He is quite aware that many other patented systems have not been exemplified, the reason being that his object was not to compile a complete category of all the methods in which reinforcement can be applied to concrete. On the contrary, it was to describe and illustrate structures that are fulfilling useful purposes in this and other countries, and so to demonstrate the universal applicability of reinforced concrete to bridge construction of every kind, from the modest footbridge to the largest highway or railway viaduct. The attention of railway engineers may be specially directed to the new material, which is far more durable than steel under ordinary conditions and particularly so in situations where the destructive gases from locomotive funnels have to be taken into account.

(The End.)

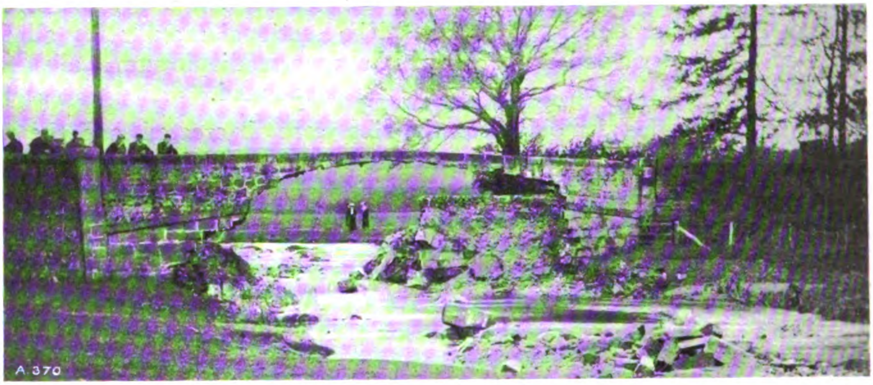
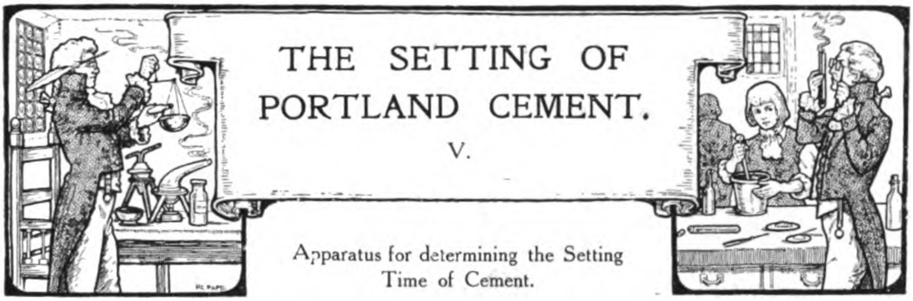


FIG. 53. LILBURN BRIDGE: VIEW AFTER THE FLOOD OF MAY 19TH, 1906.



THE SETTING OF PORTLAND CEMENT.

V.

Apparatus for determining the Setting Time of Cement.

By PROFESSOR M. GARY (Berlin).

To all engaged in constructional engineering, and more particularly in the application of concrete and reinforced concrete, the question of the setting of Portland cement is one of the utmost importance. Having regard to this, arrangements have been made by which a series of articles will be presented by well-known authorities at home and abroad, dealing with the question in its chemical and physical aspects, and these various articles will finally be summarised with the view of presenting the more important facts and the consensus of opinion. The attention accorded to the earlier article has encouraged us to extend our list of contributors on this subject to the leading authorities of other countries. Correspondence is invited, as a free discussion of the various arguments put forward will be welcome to all who have this subject at heart.

The author, Professor Gary, first prepared the data given below for a paper to be published in the Records of the Prussian Royal Testing Station at Gross Lichtefelde, and courteously placed an advanced proof at this journal's disposal for translation.—ED.

IN *Le Ciment* of January, 1906, M. Louis Périn criticises the registering apparatus designed at the Gross-Lichterfelde Testing Station for determining the setting-time of cement, objecting to the "identification" of the evolution of heat during the setting of Portland cement with the process of setting itself. It is, he considers, necessary to fix our conceptions of setting before drawing such conclusions, and the simplest conception is said to be the following: "Setting is the sum-total of the physical and chemical phenomena which mark the gradual passage of the cement from the pasty to the solid state." According to this definition, M. Périn remarks, it is impossible to treat the evolution of heat and the setting as identical, since setting is the sum-total of the phenomena of which the evolution of heat is but one. Although a certain connection between the setting and the evolution of heat is admitted, M. Périn considers the use of the photographic apparatus for the determination of setting times as unjustifiable, the apparatus being merely a form of automatic calorimeter, and recommends the "Périn prisometer," described in *Le Génie Civil* of June 4th, 1904.

Curves of setting cement, taken with this apparatus, were published in *Le Génie Civil* of April 15th, 1905, and similar curves of setting plaster of Paris appeared in *La Céramique* of August, 1905. M. Périn remarks that if experiments were made with his apparatus and that of the Testing Station it would probably be found that two different curves would be obtained. If M. Périn had himself conducted such experiments, before condemning an apparatus unfamiliar to him, he would have found the above statement to be only apparently true, as is shown below. In a paper read before the French and Belgian members of the International Association for Testing Materials on May 13th, 1906, M. Périn has described his apparatus, and there calls it an "automatic Vicat needle."* This needle is depressed by clockwork once a minute for plaster, once every 20 minutes for cement, and records the depth of penetration as an arc on a uniformly rotating drum. The clockwork runs for 13 hours.

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* The apparatus is figured and described in the report of the meeting of May 13th, 1906, p. 21.

In discussing his apparatus and curves, M. Périn again condemns the German calorimetric experiments, which he considers of interest as determining the rise of temperature, but unsuitable for the determination of the setting time.

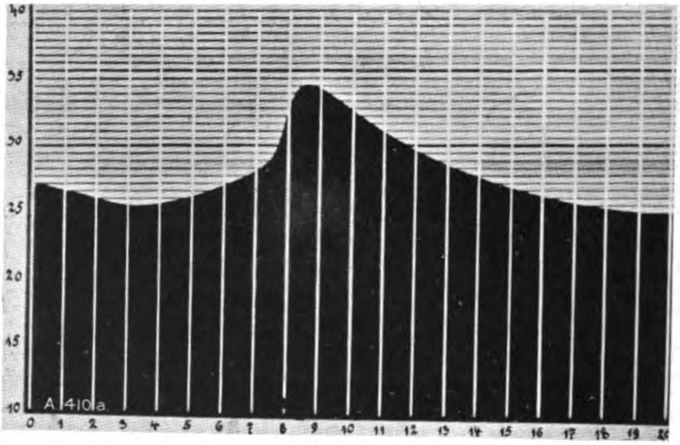

FIG. 1.

It is not immediately possible to refute this opinion, but experience leads to a different conclusion. Experiment should precede judgment. The *Tonindustrie-Zeitung* requested the use of a Périn apparatus in order to test it, but the request was refused, on the ground that M. Candlot was about to report on his experiments to the Brussels Congress.† In the meantime experiments may be described which have been collated at Charlottenburg and Gross-Lichterfelde with both forms of apparatus.

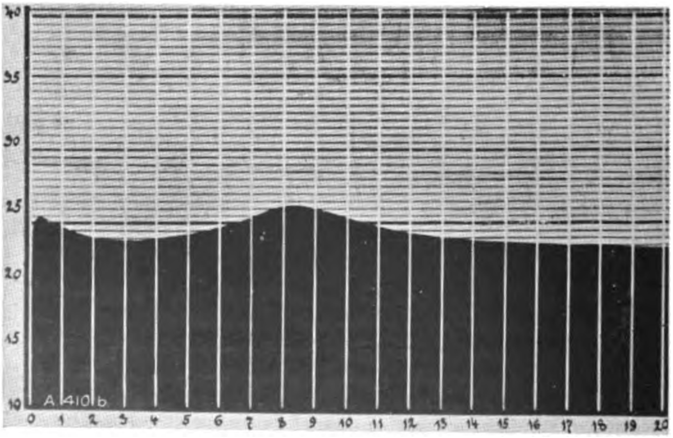

FIG 2.

Since the setting process depends mainly on chemical changes, it is clear that a close connection must subsist between the heat produced by these chemical reactions and the process of solidification. Numerous experiments made at Gross-Lichterfelde have confirmed this. It has been found that with a few exceptions (cement of special type) the maximum evolution of heat falls very near to the point designated as the "setting point" in tests with the Vicat needle.

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† This paper has unfortunately not been received.

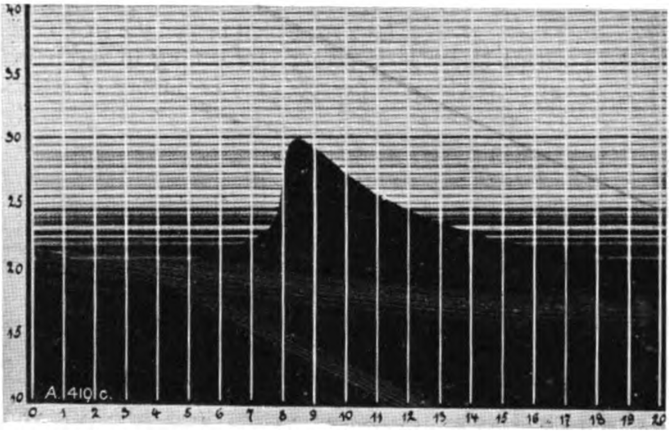

FIG. 3.

Attention has already been drawn to this fact in the Reports of the Association of German Portland Cement Manufacturers (1905, p. 156-157, and 1906, p. 94-95), and a few examples are selected therefrom (Table 1 and *Figs.* 1-9). The first six cements are slow-setting, the three remaining are quick-setting.

TABLE 1.

	Setting-Time in Minutes by the			
	Heat-Evolution Curve.		Needle.	
Figure.	Beginning.	End.	Beginning.	End.
1	210	510	300	510
2	210	495	210	450
3	240	510	390	540
4	285	600 apparent really 1100 *	345	645 apparent
5	270	540	285	525
6	240	480	285	540
7	2	15	2	4
8	5	40	13	15
9	instantaneous	70	40	60

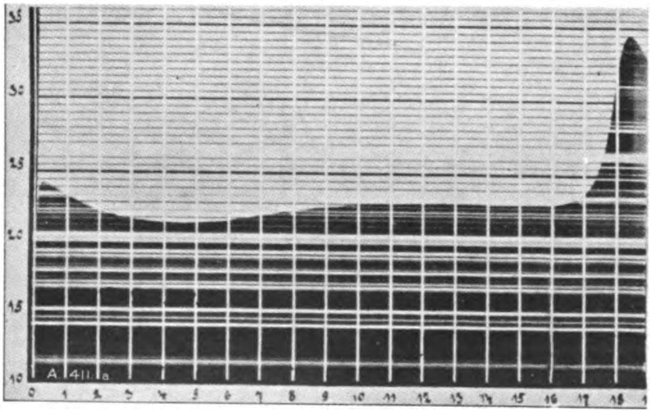

FIG. 4.

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* See *Fig.* 4. The cement was apparently set after 10 to 11 hours. After this the needle made no perceptible impression on the surface of the pat, but after 16½ hours hardening the cement showed a sudden rise of temperature of 11·5 deg. C., so that the "setting" was only then complete.

It will be seen that observations with the needle give almost the same results as those obtained photographically. Complete concordance was not to be expected, since, as is known, a series of successive needle tests frequently give divergent results. With quick-setting cements the heat curve lags somewhat behind the solidification of the pat, but this is of no practical importance, as cements setting in 4-15 minutes are quite exceptional. The heat curve, however, records the beginning of setting earlier than the needle test. The photographic method also avoids the defect of the needle, which consists in the inability of the observer to determine whether a "perceptible impression" is made or not, and also the possibly defective mixing of the mortar giving rise to lumpiness in the cement and the formation of a hard outer skin on the pat. This should be of great value, for there can be no doubt that a cement mortar should not be disturbed after the chemical reactions in the interior of the mass have once set in. It is therefore important in practice to determine as accurately as possible the moment at which the chemical reactions begin in a cement. *Fig.* 4 shows further that the needle test may be misleading, since a pat of cement may appear hard on the outside while the reactions are still proceeding in the interior. M. Périn's apparatus, as in all forms of automatic needle, does not avoid this error, but displays it prominently, as will be shown below. One of M. Périn's examples (*Fig.* 11) is typical of such cases, which are of frequent occurrence. This could have been foreseen, even without having tested M. Périn's apparatus, since it is not the first of its kind, but the fourth known to me.

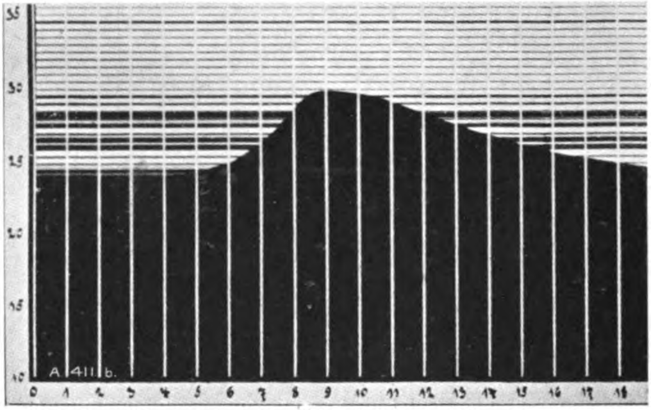

FIG. 5.

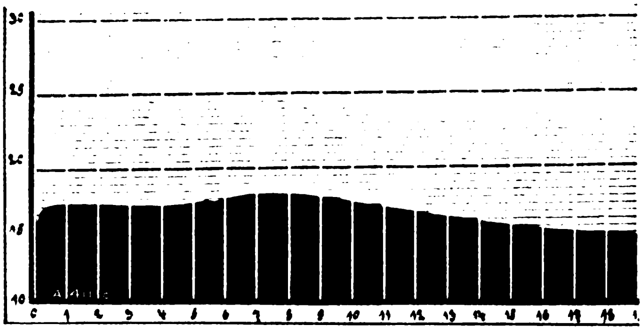

FIG. 6.

When president of the International Association, the late Prof. von Tetmajer had an automatically recording apparatus constructed by Messrs. J. Amsler-Laffon & Son, of Schaffhausen, at the end of the 'eighties.* This apparatus had the great advantage that the number of depressions of the needle per unit of time could be varied at will, and that it continued to run for four days when working at 15 minute intervals. It did not, however, fulfil expectations. Prof. von Tetmajer himself gave up its use, and the Charlottenburg Institution, where it was tested for a long time, soon recognised that its records were untrustworthy, and did not correspond with the indications of the normal Vicat needle. Cement is extraordinarily sensitive to shaking during setting, and the apparatus shook the pat of cement at every fall of the needle and at each rotation of the box holding the cement.

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* Reports of the Building Material Testing Station, Federal Polytechnic of Zürich, 1893, p. 100—106

Fig. 12 shows the details of construction of the Tetmajer apparatus. It is obvious that it is in principle the same as that of Périn, but Tetmajer employs flowing water as a motive power and Périn clockwork. Tetmajer's record is also taken as a spiral on a flat disc, and Périn's as a series of arcs on a drum.

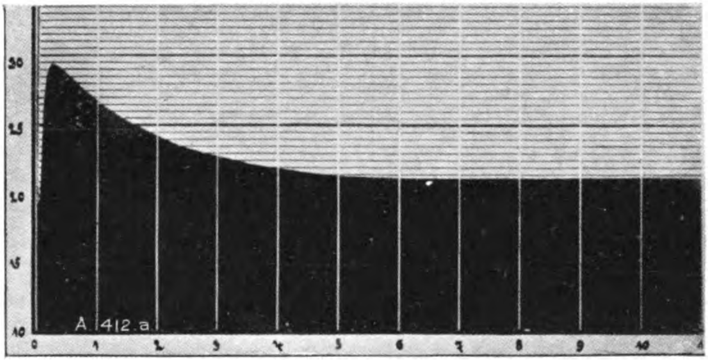

FIG. 7.

A second apparatus for recording the setting time of cement is of English origin.† It was constructed by Prof. Goodman, of Leeds, and known as Goodman's Cement Tester. A small wheel, carrying a weight of 2½ lb., dips into a trough 1 ft. long filled with cement, and has a rolling motion of 1 in. per hour imparted to it by clockwork, a pencil attached to the axis of the wheel then tracing the setting curve. *Fig.* 10 shows three curves obtained with this apparatus. The length of the trough is frequently insufficient for recording the process to its end.

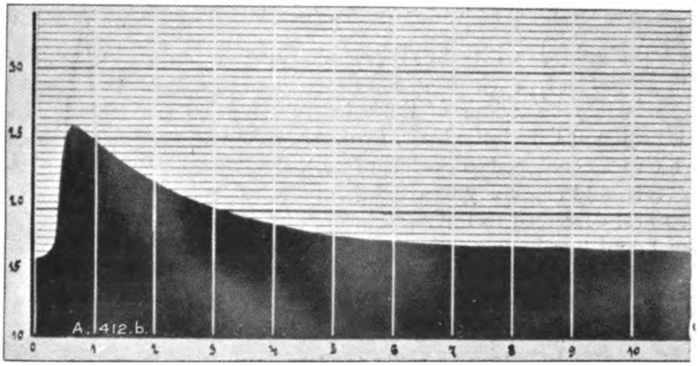

FIG. 8.

I reported on both forms of apparatus (Tetmajer's and Goodman's) to the International Congress for Testing Materials at Budapest in 1901.* Both were tested at the Material Testing Station and compared with the Vicat needle, but could not be brought into correspondence with the latter, as is shown by the comparison in Table 2.

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† Report of the Association of German Portland Cement Manufacturers, 1895, p. 55.

* Gary. "The Present Position of Cement-Testing in Germany," p. 15.

TABLE 2.

Mark of Cement.	Commencement of Set. Minutes. Vicat.	Commencement of Set. Minutes. Amsler-Laffon.	Commencement of Set. Minutes. Goodman.	Setting Time. Minutes. Vicat.	Setting Time. Minutes. Amsler-Laffon.	Setting Time. Minutes. Goodman.
A	30	33	22	185	552	168
B	45	40	30	83	229	90
C	210	120	53	390	609	213
D	200	199	81	420	607	222
E	192	298	155	427	706	371
F	204	293	184	394	955	401
G	68	65	54	163	340	129
H	190	475	—	670	1940	—
I	34	30	34	230	616	230
K	29	33	80	218	255	202
L	128	99	102	428	990	252
M	125	113	—	1140	2081	—
N	4	20	—	23	166	—
O	420	226	—	615	746	—

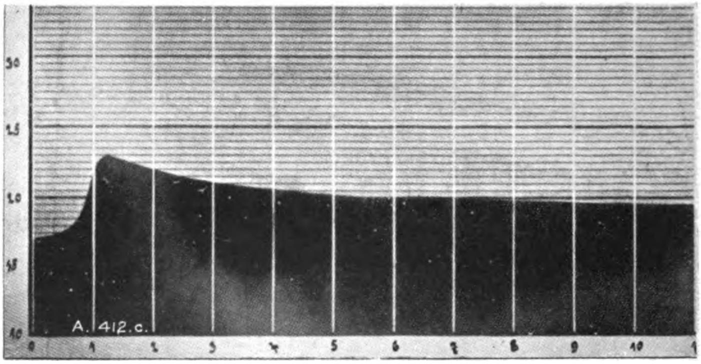

FIG. 9.

The results obtained with the three instruments differ widely, without any regularity being apparent.

The unsatisfactory behaviour of these instruments led the Director of the Royal Experimental Station at Charlottenberg, Prof. A. Martens, to construct a new automatic apparatus, which was designed to conform as closely as possible to the conditions of use of the Vicat needle, and especially to avoid the undesirable shaking of the cement. This apparatus was first described to the Association of German Portland Cement Manufacturers in 1897,† and has been again described in the Memorial of the Royal Testing Station, p. 339. In this apparatus three Vicat needles of the usual form are arranged side by side. The samples are mixed in oblong boxes. A cam moved by clockwork cuts out the sustaining magnet at definite intervals, and the needles descend slowly into the cement, into which they can penetrate freely as with the Vicat needle. After half a minute they are again raised to the original position, and at the same time the table carrying the sample is slowly moved through a definite distance. This operation is repeated every 1, 5, 15 or 30 minutes, according to the cam employed. The depth of penetration of the needles is recorded by tracing pens. *Fig.* 14 shows the external appearance of the apparatus, and *Fig.* 13 shows two tracings, obtained with the same cement, but using needles I. and III. respectively, depressed every quarter of an hour. Needle I. shows the first rise at the second contact, needle III. not until the sixth. Sometimes still

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† Report for 1897, p. 165.

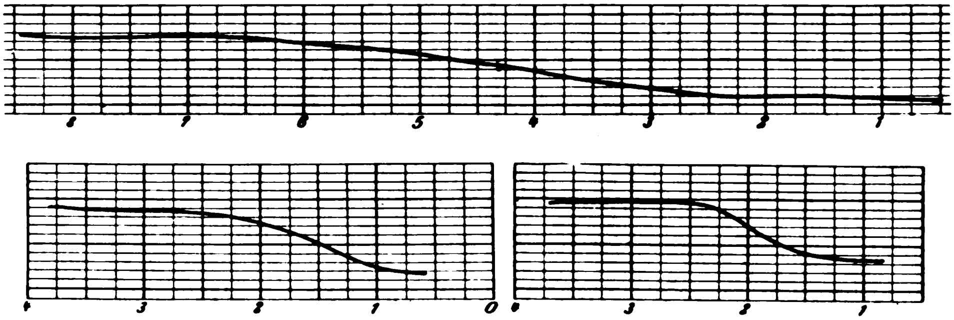

FIG. 10. In Fig. 10 italic numerals indicate hours.

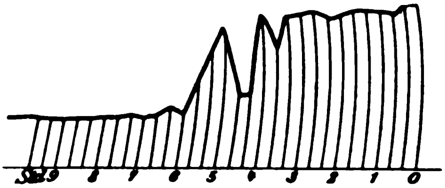

FIG. 11.

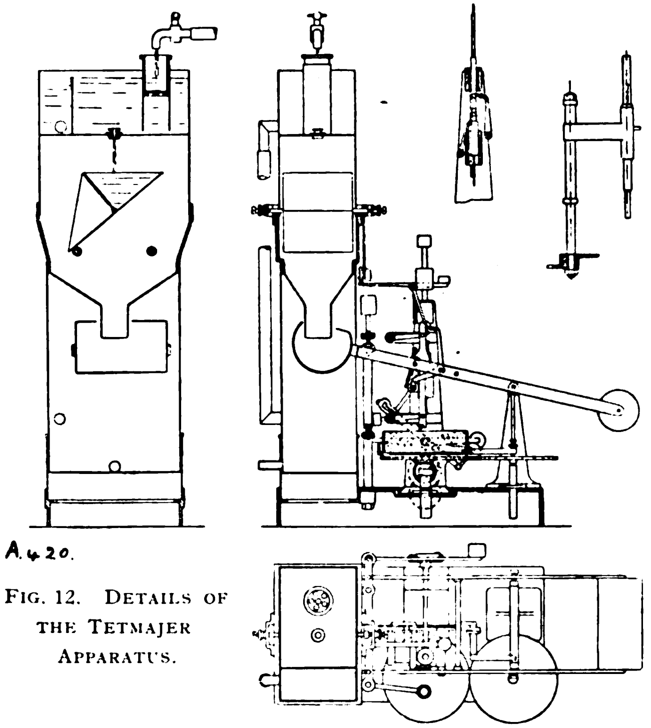

FIG. 12. DETAILS OF THE TETMAJER APPARATUS.

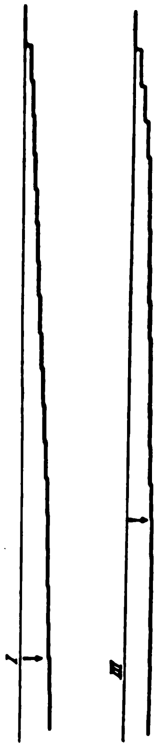

FIG. 13.

greater differences are found, depending on whether the needle meets with a hard particle which resists its penetration or not. Uncertainties often arise in this way, making a repetition of the experiment necessary, which is not the case with the hand needle, since it is usual at each test to depress the needle in several places near one another, making it easy to recognise the presence of hard particles. These peculiarities, noticed with Marten's apparatus, although carefully constructed and working almost without vibration, would certainly occur in tests with Périn's apparatus, and, therefore, it is not to be expected that it will come into practical use.

In the choice of an apparatus for the practical determination of the "setting time" of a cement, the following facts should be noticed.

It is in practice quite immaterial whether a slow-setting cement sets in 6, 8, or 10 hours. Insistence on determined "setting times" in public specifications must be regarded as mischievous. It is entirely sufficient to determine whether a cement is quick or slow-setting, but it is of great interest to know, before use, *how* it behaves during setting, whether it suddenly hardens after a long interval, or gradually solidifies with slight evolution of heat. Nothing gives such certain information on this point as the curve of heat development, since this brings the chemical processes in the interior of the mass under direct observation. One of the pioneers in cement testing, Faija, remarked some years ago :*

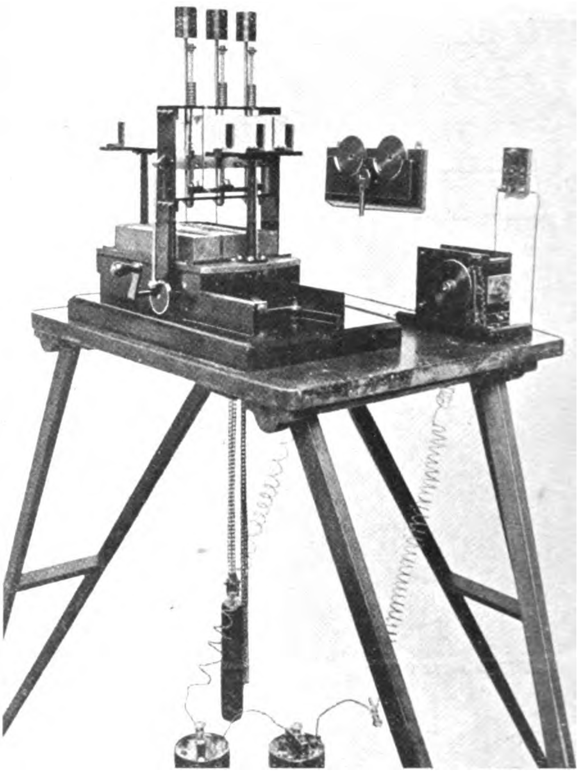

FIG. 14. PROF. A. MARTEN'S APPARATUS.

"When a cement has been mixed and moulded, the first effect observed is the appearance of water on the surface; the next is the absorption of this water by the cement and the beginning of a development of heat; finally, the cement returns to its original or normal temperature, the last stage of which is called 'setting.' This has nothing to do with the hardening, since many cements are hard enough to resist the pressure of the finger-nail before, and others only long after, the point at which the author regards a cement as set." Whether in building a cement is hard enough to resist the pressure of the finger-nail or Vicat needle within a prescribed time or not, is usually unimportant; but it is important that it should be worked before its chemical energy has been developed, as shown by the evolution of heat. Since the time of hardening is longer the more sand is added to the mortar, and since neat cement is seldom used, it is important to know the course of setting, not merely in neat cement, but in mortar. No needle apparatus is suitable for this purpose; on the other hand, the temperature-curve gives information also as to the setting of mortar.

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* *Tonindustrie-Zeitung*, 1897, p. 1080.

Steel and Concrete at the Ritz Hotel, London.

Although considerable space is being accorded in these columns to reinforced concrete, the importance of steel frame construction encased in concrete should not be underrated as a most practical and rapid means of construction, more particularly where the design is not of a too complicated character.

In the following article we present an example of steel frame and concrete construction which should rank high in the building annals of the Metropolis, and the execution of which reflects great credit upon the contractors. This example, however, again shows the regrettable manner in which modern forms of steel frame construction are handicapped by unsuitable and antiquated building legislation; and the ridiculous thickness of exterior walling that has to be employed without practical purpose, solely to meet the requirements of the London Building Act, is certainly a disgrace to the capital city of a great empire.

We are indebted for three of the illustrations presented to the "Builders' Journal."—ED.

STEEL AND CONCRETE AT THE RITZ HOTEL, LONDON.

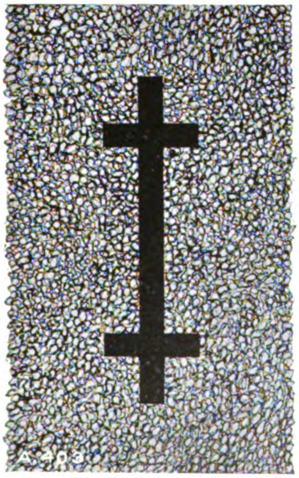

FIG. 1.—RIBBED BAR IN CONCRETE.

As mentioned in our issue of March last, the Ritz Hotel is a good example of skeleton building construction, the essential features of the design being, in fact, the same as those characterising the most modern steel-framed buildings in the United States. All the dead loads, including the weight of the steelwork, the walls, floors, and roof, and nearly the whole of the superloads represented by the fixtures, furniture and inhabitants of the hotel, are transmitted by the members of the roof system, and the columns, trusses, girders, beams, and joists incorporated in the walls and floors, to main columns, whence they are distributed over the ground by extended footings of special design.

No one who passes along Piccadilly, and stops to examine the building, would imagine that this method of construction had been followed, for the main walls and piers are apparently massive enough to carry the entire weight of the structure and its contents. The great thickness of these portions of the hotel was not adopted by the architects for the sake of strength, but simply in deference to the regulations of the London Building Act, whose irrational character has been sufficiently discussed in a previous article.*

In reality, instead of imparting increased strength, the walls simply have the effect of creating a totally unnecessary load which has to be carried by the steel framing, and if this had not been made of greater strength than would otherwise have been requisite, the superabundant thickness of brick and stone masonry might have constituted an element of weakness. Thus the outer shell of the structure practically consists of a series of curtain walls, chiefly serving the purpose of a screen between the interior of the hotel and the outer air.

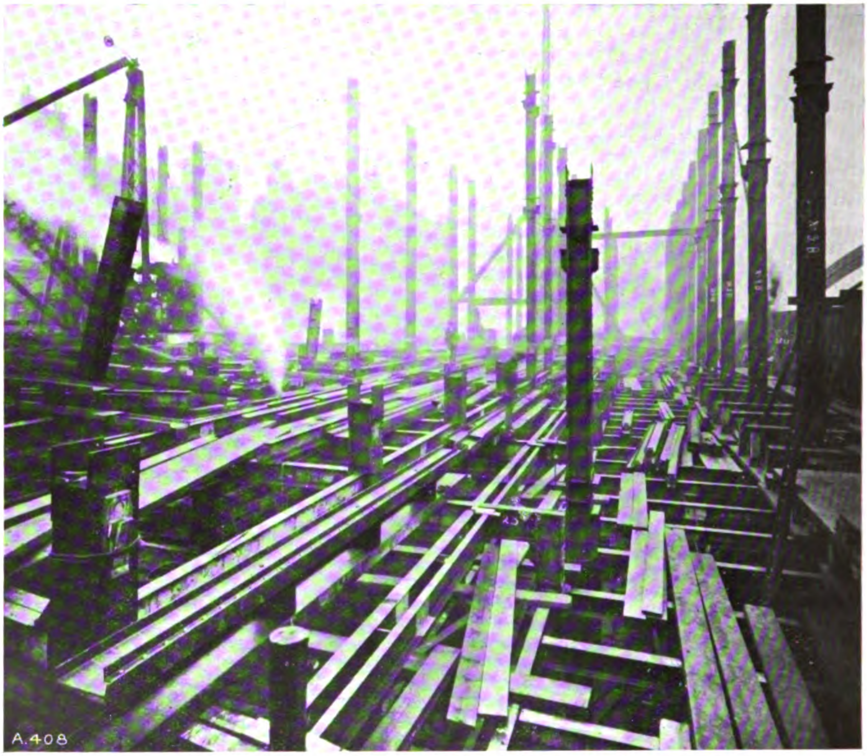

FIG. 2. THE ERECTION OF STANCHIONS.

GENERAL DESCRIPTION.

Standing in a prominent position between the Green Park and Arlington Street, the Ritz Hotel covers an area of about 23,000 square feet, and the length of its three façades are as follows: Piccadilly, 231 ft. 4½ in.; Arlington Street, 115 ft. 2¼ in.; and Green Park, 87 ft. 1⅛ in. From these dimensions and by reference to the plans in *Figs.* 5 and 6, it will be seen that the boundaries on Piccadilly and at the back of the building are by no means parallel. Those on Arlington Street and Green Park are nearly so, the interior angle at the corner of Arlington Street being 83 deg. 3 min., while the complement of the interior angle at Green Park is 83 deg. 63 min. The level of the ground floor, which was taken as a datum for constructional purposes, is 1 ft. 6 in. above the pavement level of Piccadilly at the centre of the main entrance. Below hotel datum there are two floors, that of the basement at a depth

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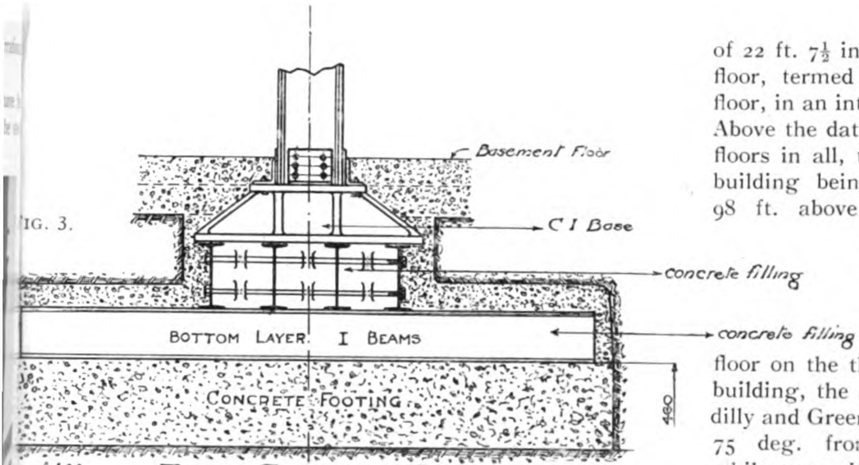
* "Steel Skeleton Construction and the London Building Act." See Vol. 1, No. 1.

IG. 3.



·TYPICAL·SECTION·OF·GRILLAGES·

of 22 ft. 7½ in., and a mezzanine floor, termed the lower ground floor, in an intermediate position. Above the datum there are seven floors in all, the flat roof of the building being at a height of 98 ft. above hotel datum, or 96 ft. 6 in. above pavement level. Mansard roofs have been adopted above the sixth floor on the three façades of the building, the slope on the Piccadilly and Green Park fronts being 75 deg. from the horizontal, while to avoid the possibility of interference with ancient lights, the slope of 45 deg. was employed from the fourth floor upwards on the Arlington Street front. Three pavilions rise above the flat roof of the hotel (see *Fig.* 16), the outer walls of these structures continuing the lines of the sloping roofs. The height of the pavilions above hotel datum is about 115 ft. at the highest point.

The outer walls of the building are of brick faced with granite up to the first floor, and Portland stone above that level on the Piccadilly, Arlington Street, and Green Park frontages, the thickness of the masonry ranging from 3 ft. 3 in. at the

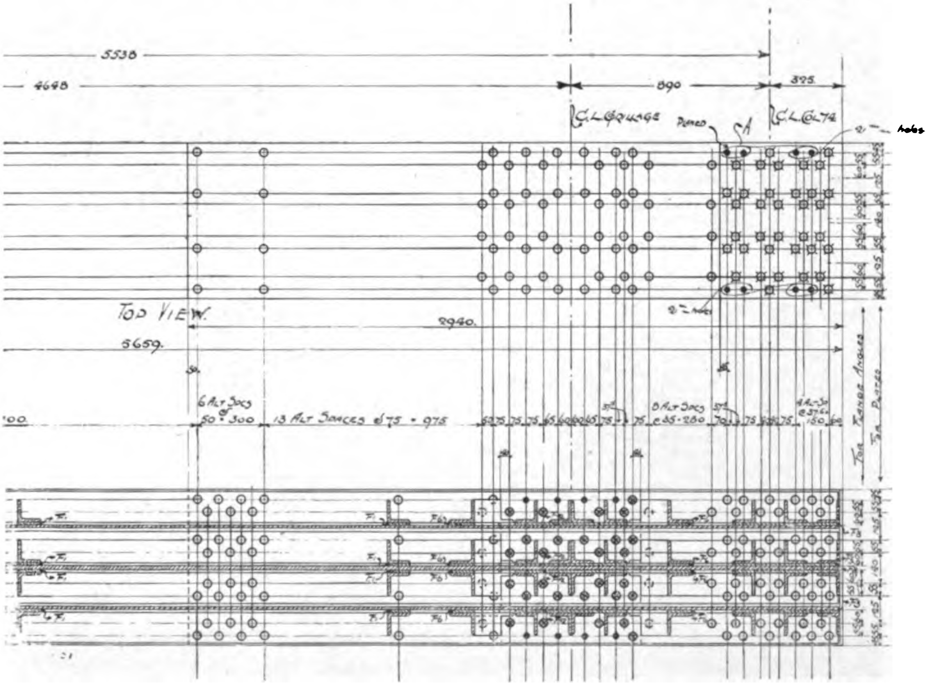


FIG. 4.—ELEVATIONS AND SECTIONS OF CANTILEVER FOUNDATION GIRDER.

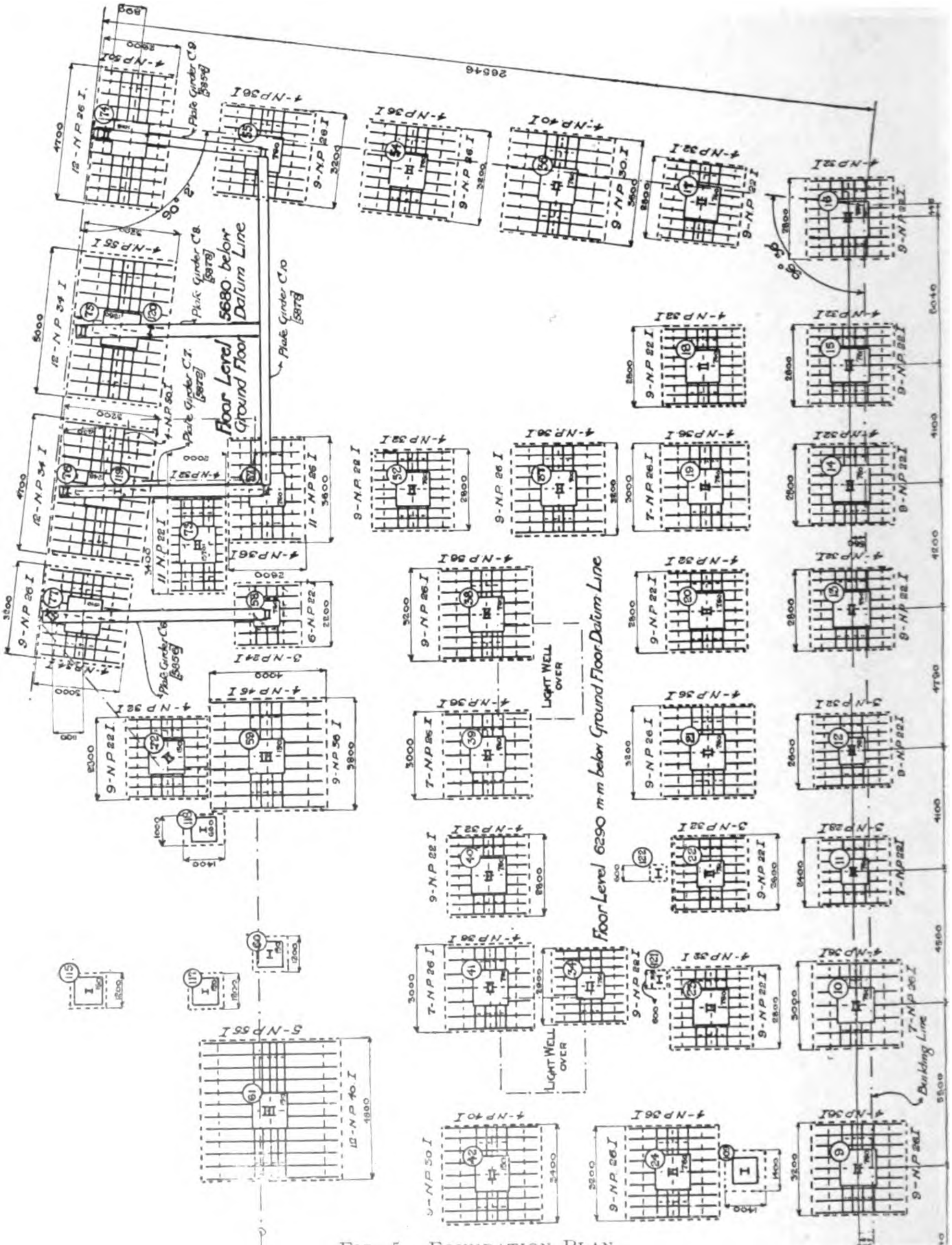


FIG. 5.—FOUNDATION PLAN.

ground floor to 14 in. at the sixth floor. A recent view reproduced in the heading gives an excellent idea of the finished structure. In the interior the Louis Seize style of decoration has been adopted throughout, and every effort has been made to provide for the comfort of visitors. The most noteworthy feature of the hotel is the broad

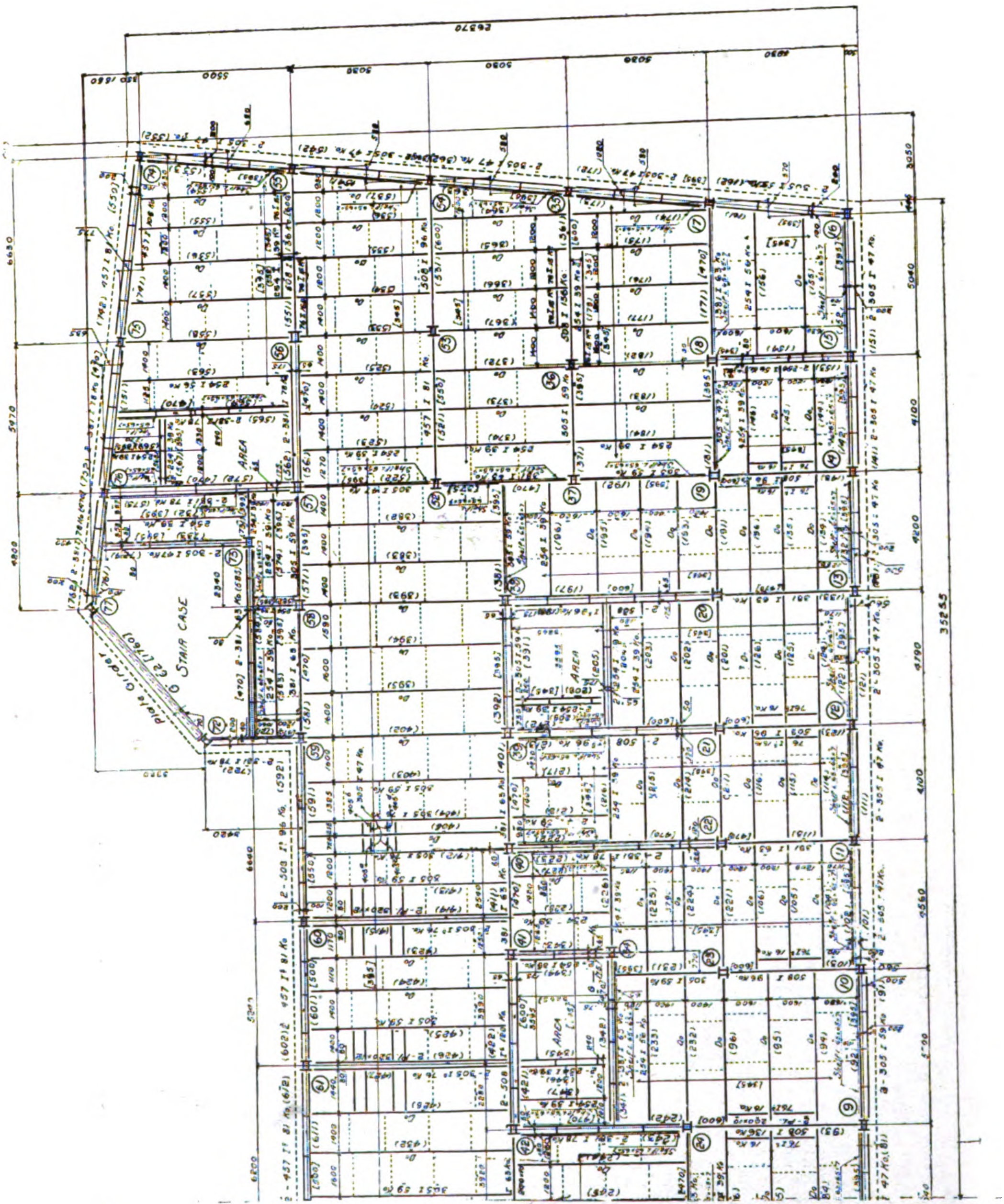


FIG. 6.—FRAMING PLAN, THIRD FLOOR.

vaulted gallery, broken up by arches into a series of lounges and halls, and extending from the Arlington Street entrance to the grand restaurant overlooking the Green Park. This gallery is built in stone, and opens into a winter garden opposite the main entrance from Piccadilly. The finest apartment in the hotel is the restaurant,

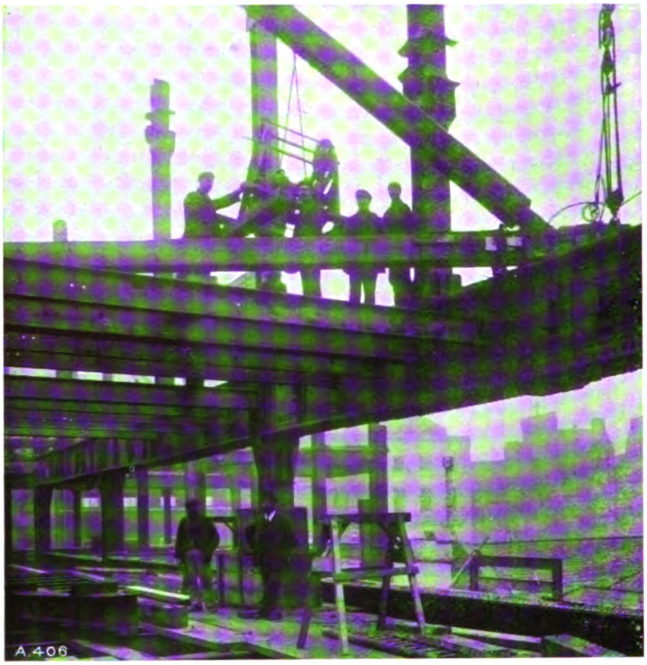


FIG. 7.—VIEW OF A MAIN GIRDER.

which is panelled in marble and has a fine painted ceiling. The lower ground floor contains a large banqueting hall immediately below the restaurant reception rooms, and private dining rooms. On the upper floors the accommodation includes 150 bedrooms and sitting rooms and 75 bath rooms. Fire-resisting construction of the most approved type has been adopted throughout, and the greatest care has been taken to afford protection against corrosive influences by covering the steelwork, wherever possible, with concrete, brick, or terra cotta, but chiefly—we are glad to see—with Portland cement concrete, which is without doubt the best material for the purpose.

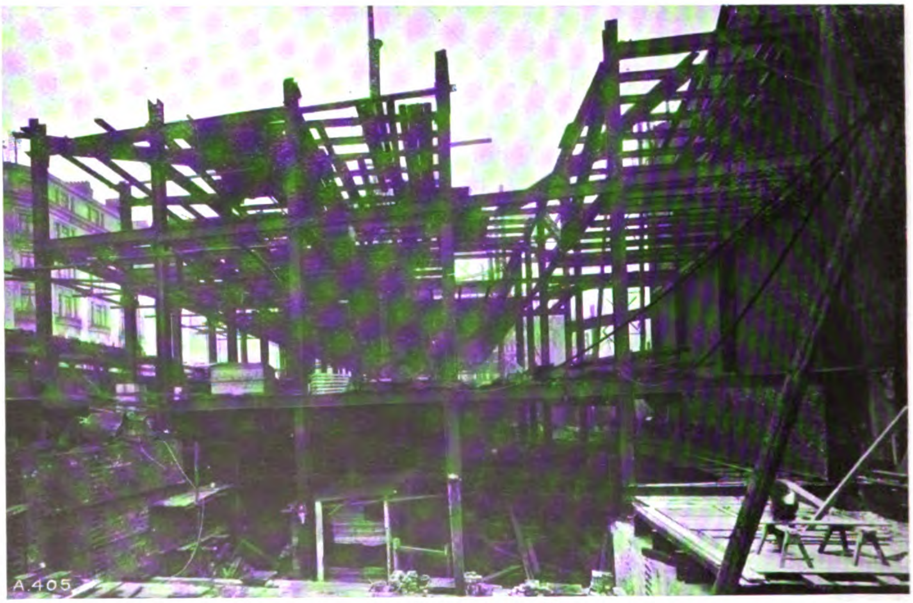


FIG. 8.—A GENERAL VIEW.

Having now before us the main features of the Ritz Hotel, we propose to give some details relative to the foundations, the steel framework, and the reinforced concrete construction of the floors and roofs. It should here be mentioned that on the various drawings reproduced as illustrations to this article all dimensions are given in millimetres. For the convenience of the reader requiring approximate equivalents during perusal of the article, we may suggest that if millimetres be multiplied by 4 and a decimal point be inserted in front of the two last figures in the product, the result will be the corresponding measurement in inches within about 0.06 per cent.

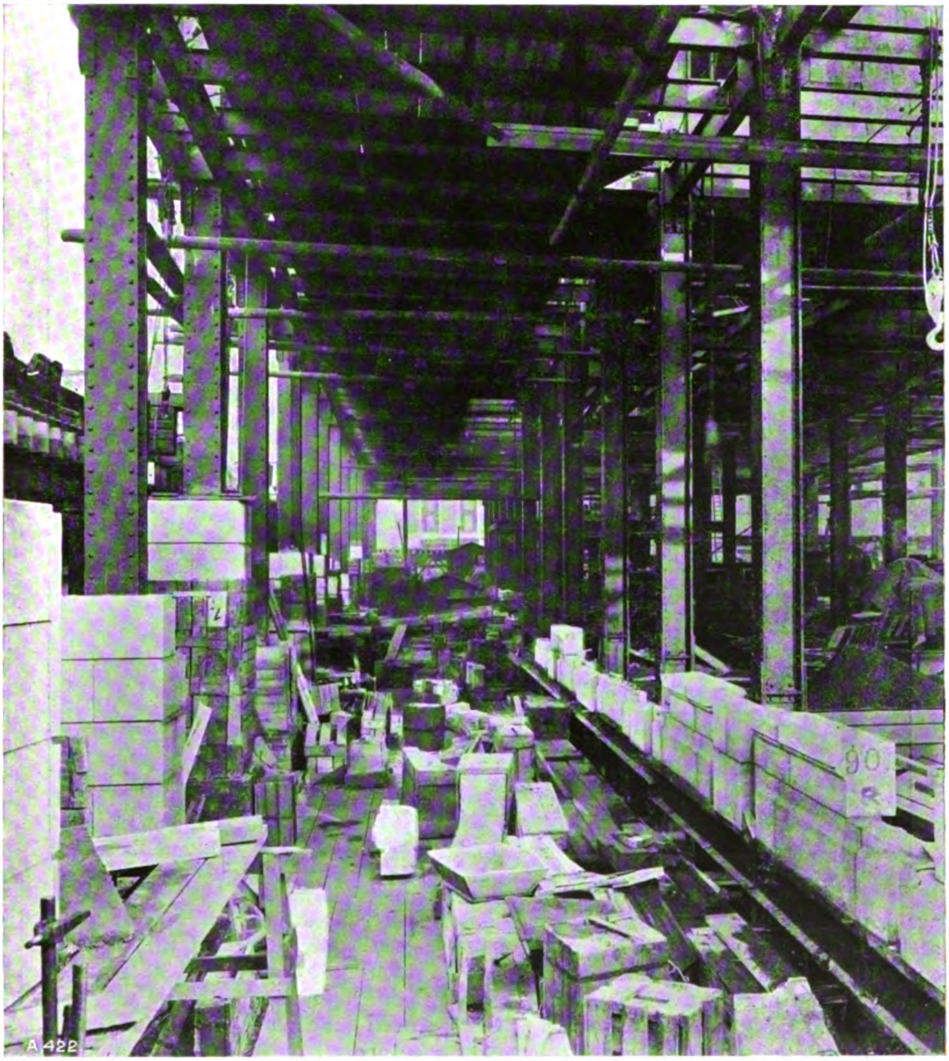


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FIG. 9.—VIEW ON GROUND FLOOR LEVEL.

FOUNDATION.

As will be seen by the foundation plan (*Fig.* 5), the columns transmitting the entire weight of the building to the ground are arranged in rows parallel, as far as possible, with the Piccadilly frontage. The number of columns varies in the different storeys, as in some parts of the building the columns do not extend higher than the ground floor and in others they only commence above the first floor. In the framing of the ground and lower ground floors there are 118 columns; and in the framing of the upper floors there are 88 columns. Altogether 550 columns and stanchions are included in the building. All columns carrying floors and walls are supported at basement level upon massive cast iron bases, the average area of which is about 9 sq. ft. The load is distributed over concrete footings by means of steel grillages composed of two sets of I-beams, the upper set being laid transversely to that below. All beams in the grillages are securely tied together by means of $\frac{3}{4}$-in. bolts and nuts, and are maintained at the predetermined distance apart by cast iron separators $\frac{3}{4}$-in. thick. The spaces between the beams are filled in with well-rammed concrete, and the same material has been applied outside the steel to the thickness of 4 in., as a protection against corrosion and fire. The footings below the grillages are of mass concrete, 18 in. thick, deposited in pits excavated in the clay below basement floor level. The areas of the grillages and concrete footings necessarily vary with the loads to be carried, but the average dimensions may be taken as about 13 ft. square.

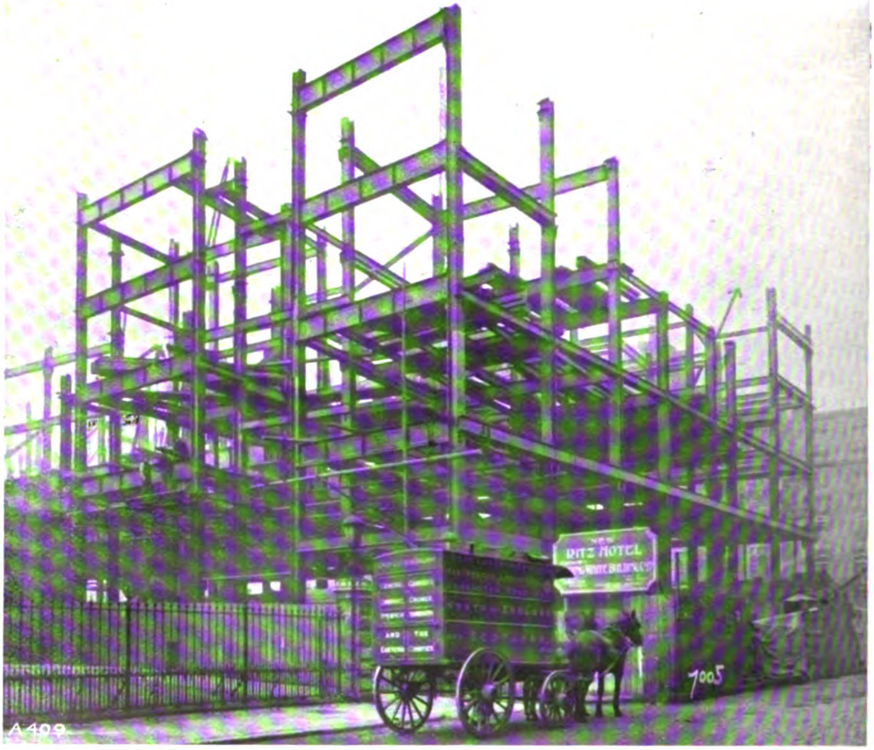

FIG. 10.—GENERAL VIEW FROM EAST SIDE.

Fig. 3 is a section showing a typical column base with the supporting grillage and concrete footing. The following were the data employed for calculating the dimensions of the foundations :—

Safe load on earth ...	5,000 lb. per sq. ft.	Weight of Portland stone...	150 lb. per cb. ft.
Weight of brickwork in cement	120 lb. per cb. ft.	Weight of floors (including steel)	100 lb. per sq. ft.
Weight of granite... ...	170 lb. per cb. ft.		

It should here be mentioned that the weight of the various floors, including girders, beams, and joists, does not exceed from 80 lb. to 90 lb. per square foot, and that the reason for taking 100 lb. was to allow sufficient margin for the weight of terra cotta partitions, pipes, air ducts, and other interior fittings. The average net weights of the reinforced concrete flooring without taking the steelwork of the skeleton into account were 35 lb. per sq. ft. for single floors and 50 lb. per sq. ft. for double floors.

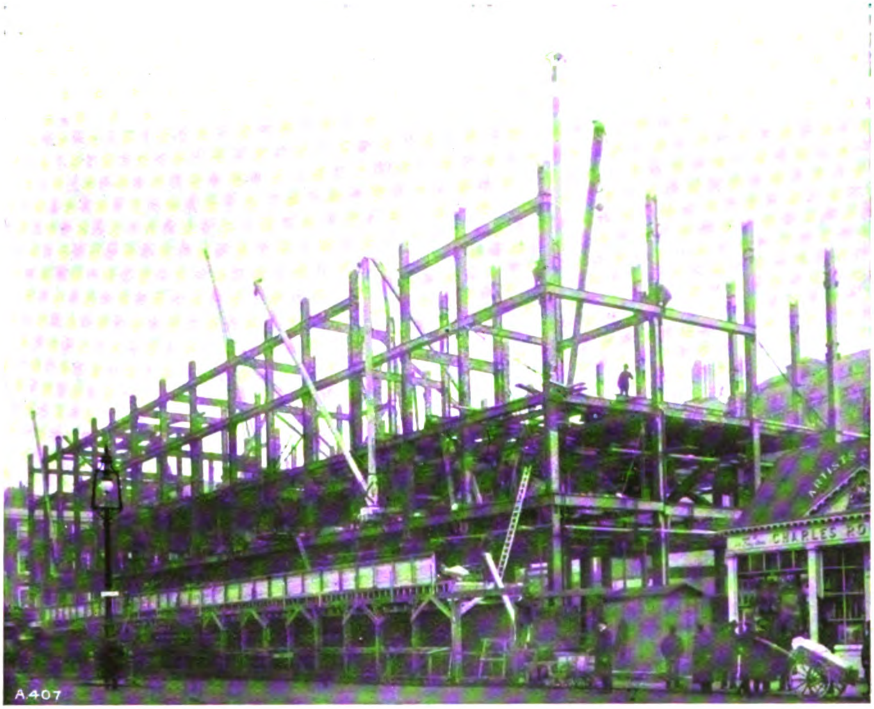

FIG. 11.—VIEW FROM THE NORTH-WEST DURING ERECTION.

COLUMNS.

The cast iron column bases are levelled on the top of the steel grillages by steel wedges, and the space of about ¾ in. so left enclosed by clay so as to form a mould for the cement grout pumped in through holes left in the bottom plate of each base. In most of the cases the bottom plate is 1¾ in. thick, the transverse, longitudinal, and diagonal ribs being 1½ in. thick. (See *Fig.* 5.)

Owing to the thickness of the walls adjoining Wimborne House at the back of the hotel, it was necessary to introduce cantilever girders for supporting some of the outer columns so as to keep the foundation grillages within the building line of the site.

Fig. 4 contains an elevation and sections of a typical cantilever foundation girder, the right hand end carrying the wall column and the left hand end riveted to an interior column. Near the right hand end the cantilever rests upon a cast steel support. There are nine cantilever girders of this type in the Ritz Hotel; and although the details are not exactly the same in every instance, the general construction is fairly represented by the drawings in *Fig.* 4.

All the columns are built up of channels and cover plates, and by varying the thickness of their constituent parts, the approximately constant external dimensions of about 16 in. by 14 in. are maintained, the sectional area of metal ranging from 13.3 sq. in. up to 142 sq. in. In this way some fifteen different column sections are provided. Except in the case of certain very heavy columns, the general type of construction comprises two 12-in. channels, connected by two wide cover plates, at each end as shown by the sections at the top of *Fig.* 15, but on the upper floors of the building, where the loads are comparatively light, the channels are connected by latticed bracing. For some of the heavier loads, the channels have been strengthened by plates riveted at the back. Four exceptionally heavy columns, carrying girders which in turn support other columns commencing at the second floor level, are built up of three 12-in. channels, reinforced by six 9-in. by ¾-in. plates, and connected by four 19¾-in. by ⅞-in. cover plates. Above the second floor these columns are reduced in sectional area by the omission of the third channel, and of the additional metal in the reinforcing and cover plates. All the columns were built in two-storey lengths, and are spliced at the height of 18 in. above floor level. Every column is machined at the ends so that the surfaces are perfectly plane and perpendicular to the longitudinal axis of the member. Upon the upper end of each column a steel cap plate is riveted by means of angle brackets, and upon this plate the lower end of the column length above is secured by field-riveted splice plates. *Fig.* 15 is a typical column drawing, by which it will be seen that the design of these members was worked out with the greatest possible minuteness and accuracy. All dimensions necessary for the guidance of the makers are stated on the drawing, and the same applies to the dimensions and spacing of the rivet holes required for use during the erection of the columns on the site.

In calculating the proportions of the columns due account was taken of eccentric as well as of axial loading. In the case of columns subject to small eccentric loads, the latter were considered as being axled and the permissible unit stress taken at the reduced value of 12,000 lb. per sq. in. For the higher eccentric loads the maximum fibre stress was limited to 14,000 lb. per sq. in., all stresses being included in the calculations. The columns generally throughout the hotel are encased in concrete by the Columbian Fireproofing Company.

GIRDERS, BEAMS AND JOISTS.

In an article such as the present it would obviously be impossible to give anything like a detailed account of the beam system in the steel framework, especially as 5,200 beams of different kinds are included in the building. The general arrangement of these members is sufficiently indicated by the plan of the third floor framing reproduced in *Fig.* 6. The main girders and beams run in longitudinal and transverse lines connecting the columns on all floors of the hotel, the spans being governed by the spacing of the vertical members, while the secondary beams are spaced at intervals generally varying between 4 ft. and 6 ft. 4 in., although some shorter and some longer spans occur at various places.

The girders are connected to the columns by strong angle brackets and stiffeners riveted to the columns as shown in *Fig.* 15, the dimensions of the brackets being proportioned to the loads to be carried. None of the beams are cut or machined to fit the lower flanges of the girders on which they are carried, but the connections are

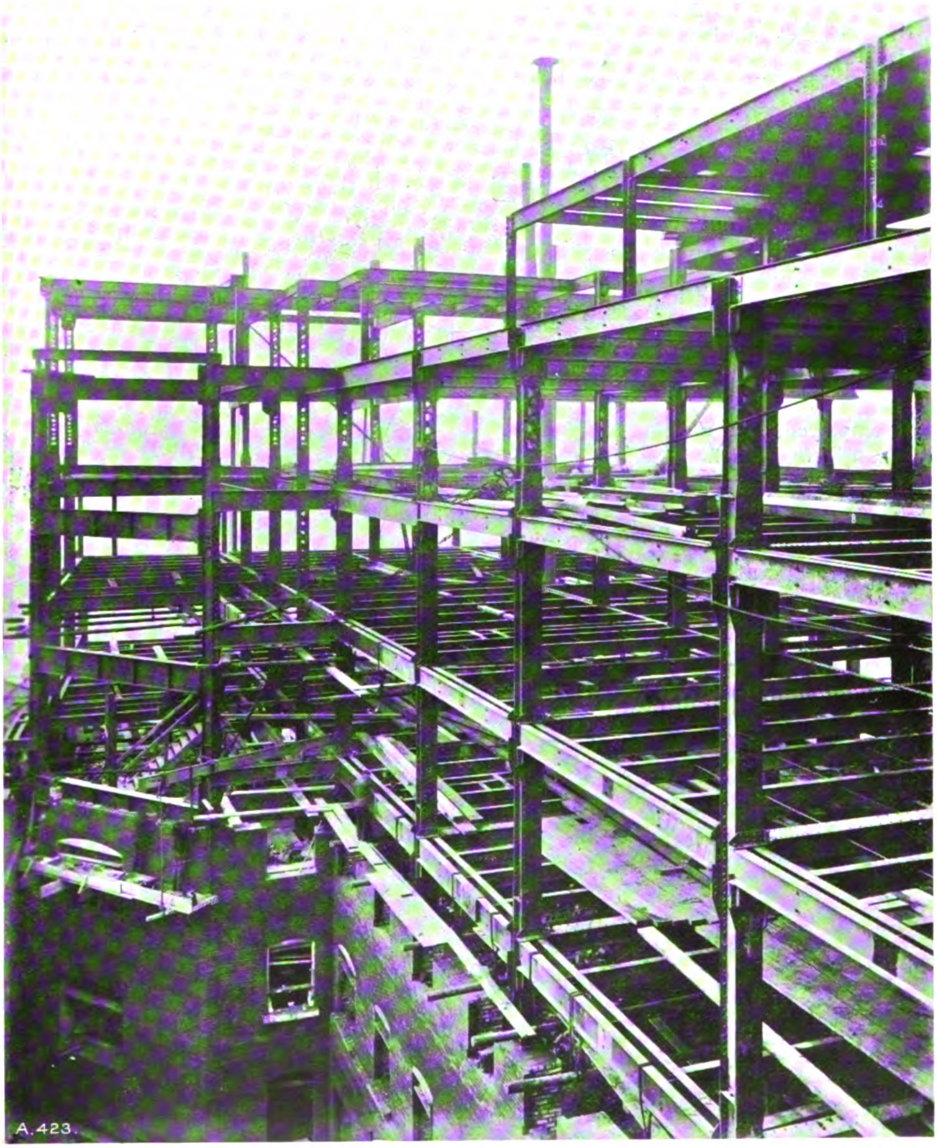

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FIG. 12.—VIEW OF STEELWORK FROM FOURTH FLOOR, LOOKING TOWARDS GREEN PARK.

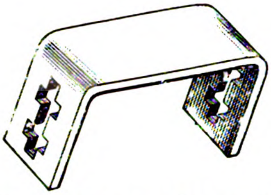

FIG. 13.—STIRRUP FOR RIBBED BARS.

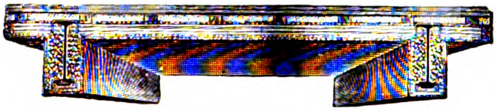

FIG. 13A.—COLUMBIAN PANELLED CONSTRUCTION.

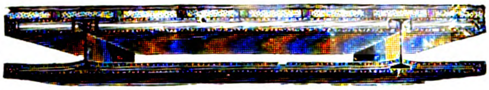

FIG. 13B.—COLUMBIAN DOUBLE CONSTRUCTION.

made by stout angle brackets giving adequate lateral support and transferring the loads as nearly as possible to the central axis. In almost every case the connections are riveted, bolts only being employed in positions where field riveting was impracticable.

In that part of the hotel overlooking the Green Park it was necessary to employ girders in spans up to about 35 ft. in order to avoid interior columns in the restaurant on the ground floor and in the banqueting hall on the lower ground floor. In other parts of the building considerable spans were also required. As a general rule heavy plate girders were used for spans of exceptional length, but above the restaurant wall trusses were employed, these members reaching from the first floor to the second floor so as to provide for carrying the intermediate columns in the storeys above. The magnitude of these giant trusses has rarely if ever been surpassed in British architectural practice.

The following were the permissible fibre stresses taken for the purpose of beam calculations :—

Rolled beams, 16,000 lb. per sq. in.

Riveted beams and connections, 15,000 lb. per sq. in.

Bearing for rivets, 20,000 lb. per sq. in.

Shear for rivets, 10,000 lb. per sq. in.

PREPARATION AND ERECTION OF THE STEELWORK.

All the steelwork used in the construction of the building was designed by Mr. S. Bylander, the engineer to the Waring White Building Co., Ltd., to whose courtesy we are indebted for the drawings reproduced in the foregoing illustrations.

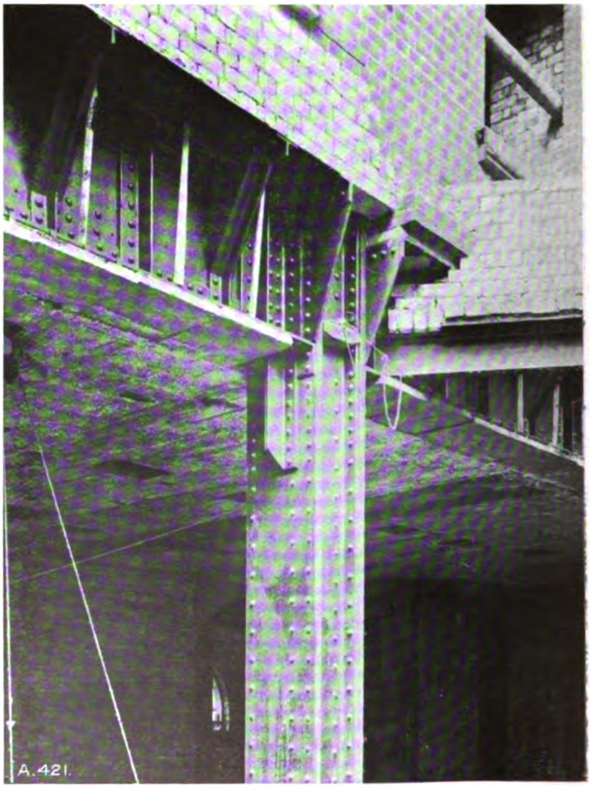

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FIG. 14.—PLATE GIRDER SUPPORTING BACK WALL.

With the object of ensuring accuracy, and at the same time avoiding difficulties in the erection of the framework, the drawings were most carefully worked out to the most minute detail, all dimensions being figured so as to leave no room for misinterpretation at the works of the steel makers. Unnecessary expenditure was avoided by the standardisation of details as far as possible. We have already mentioned the fact that all the columns were practically of the same external dimensions, a fact which permitted the adoption of standard brackets and connections for the attachment of the girders and beams and considerably simplified the manufacture of the cast-iron bases.

The undoubtedly heavy cost of the working drawings prepared in the first instance has been amply repaid by the reduced price of the steelwork and the comparative ease with which it was erected after delivery. To facilitate the assembly of the various members all of them were numbered, as indicated in *Figs.* 5 and 6. The numbering of the beams was not strictly consecutive, being arranged in such a way that it was perfectly easy for the fitters to find the beams for any given panel of the flooring. For instance, all the beams adjacent to a given column bore a number comprising one figure more than the number of figures in the column number, the first figure or the first two or first three figures of the beam number coinciding with those in the column number, while the last figure was a consecutive number indicating the position of the beam in the floor panel. Owing to the fact that the steel frame was erected quite independently of the brickwork and masonry, great care

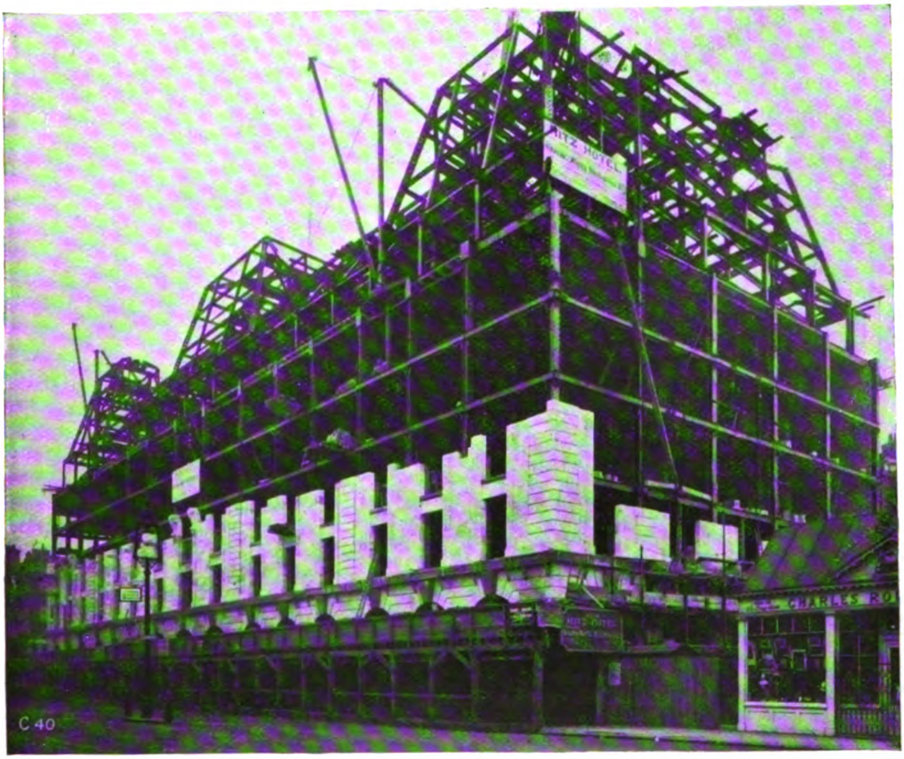


FIG. 16.—VIEW SHOWING ADDITION OF MASONRY FROM THE NORTH-EAST.

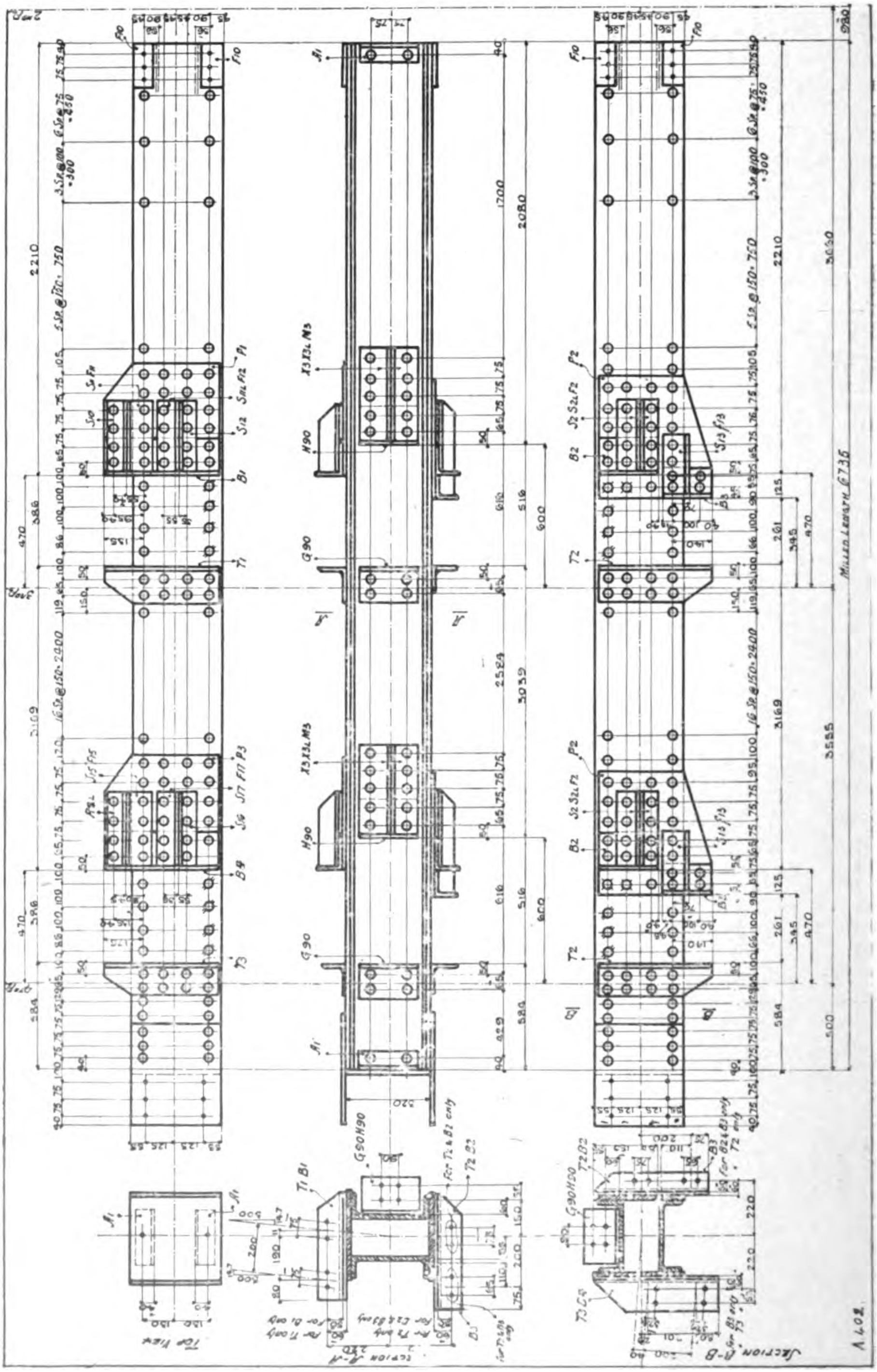


FIG. 15. ELEVATIONS AND SECTIONS OF TYPICAL COLUMNS.

was taken in the bracing of the members. This feature of the design gives an assurance of strength which is lacking in too many buildings where steel is employed as an auxiliary and not as an essential material of construction. For the purpose of erection three derricks were employed, and one 5-ton crane, and, in addition, four hoists were used for conveying materials to the upper parts of the building after the main members had been erected up to a certain height.

REINFORCED CONCRETE CONSTRUCTION.

Throughout the hotel the floors and ceilings are of concrete reinforced by ribbed steel bars on the Columbian system. Two types of construction were adopted, as illustrated in *Figs.* 13A and 13B, which represent "panelled" and "double construction floors," respectively.

In *Fig.* 13A the joists are completely encased in concrete, the lower flanges being protected by slabs, each providing an air space below the flange and held in position by anchors. The projecting ends of these anchors are turned over the lower flange, and concrete is then moulded on each side of the joist, the thickness of the covering being in all cases more than 2 in., which is the minimum recommended by the leading authorities on fire-prevention as an adequate protection against fire. Between the joists reinforced concrete slabs are moulded upon ribbed bars, of size and space suitable for the loads and spans, supported by stirrups laid over the top flange of each joist. *Fig.* 1 illustrates a Columbian bar embedded in a concrete floor slab. *Fig.* 13 represents one of the stirrups, the sides of which are perforated to afford bearing for the ribbed bars, and *Fig.* 13A shows all details of the completed floors. This type of construction was employed only in places where the projection of joists below ceiling level was not considered objectionable.

Fig. 13B illustrates the Columbian double, or flat ceiling construction, generally adopted in all parts of the building used by visitors. In this type, the floor slabs are formed as in panelled construction, but a reinforced concrete ceiling is formed between the lower flanges of the joists, leaving an air space between the upper side of the ceiling and the lower side of the floor slab, such spaces being utilised in the Ritz Hotel as ventilation ducts and as conduits for pipes, cables, and wires.

The manner in which these hollow floors were built may be thus briefly described :—

In the first place centering was fixed at the proper distance below the joists on the lower flanges of which were laid ribbed steel bars slightly bent upwards at each end to suit the slope of the flanges. Concrete was then deposited and well rammed, forming a ceiling plate, 2 in. thick. At suitable distances apart openings of oblong shape with bevelled edges were left in this plate and were afterwards closed by concrete slabs moulded with bevelled edges to fit those in the openings. Centering was next built on the concrete ceiling, and upon this the floor slab was moulded, openings being left and subsequently closed by slabs as in the case of the ceiling. The interior centering was made of short pieces of timber so that it could easily be removed in parts through the openings in the ceilings and floor slabs. After the concrete work had thoroughly hardened the ceiling and floor surfaces were finished in accordance with architectural requirements. It should be pointed out that every closed opening in the concrete is virtually a manhole, and as the exact position of each has been recorded, it will be easy at any future time to gain access to the interior of the hollow floor construction should occasion demand.

From the strictly theoretical point of view the Columbian ribbed bar involves the employment of some metal in parts of the concrete where it is of little or no service. Consequently, some small proportion of the steel may be said to be wasted. But the practical aspect of the question is that the manner in which these special bars are applied leads to a saving of labour fully sufficient to counterbalance the cost of steel not usually employed. The supporting stirrups are made in widths to suit all standard I-beam sections, and the ribbed bars require no preparation beyond cutting to length, which is done on the site by machines specially designed for the purpose. Therefore the steelwork for a Columbian floor can be laid in position very quickly by unskilled labour, and in this respect the system offers a distinct advantage over the complicated arrangements necessary under some forms of reinforced concrete.

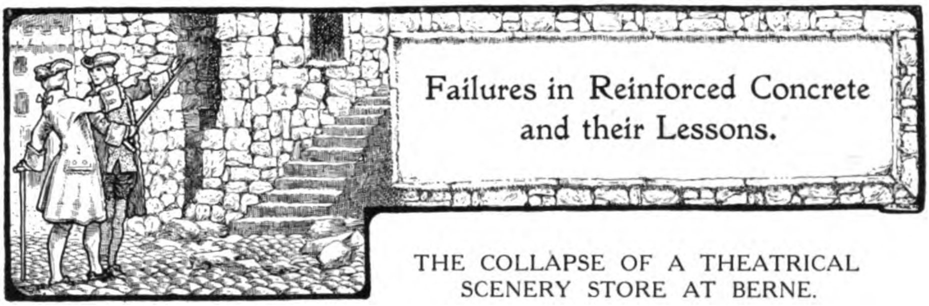
In one respect the Ritz Hotel has not afforded an opportunity for showing reinforced concrete construction in the most favourable light. We have already pointed out that the ordinary spacing of the joists in the floor framing ranges from 4 ft. to 6 ft. 4 in., the mean span being not more than 5 ft. 6 in. As reinforced concrete floors can easily be constructed in spans of 20 ft., or more, it is not at all clear why such tiny spans were adopted at the Ritz Hotel, except on the assumption that the original intention of the architects was to make use of some other type of floor requiring the support of heavy steel joists at frequent intervals.

From examination of the details of the joist and floor construction we cannot avoid the conclusions that the ribbed bars and concrete employed were of ample dimensions for spans of double the average width allowed by the predetermined spacing, and that if full advantage had been taken by the architects of the elastic strength of reinforced concrete, the number and weight of the steel joists might have been reduced by something like one half, with a corresponding reduction in the weight of the main beams, girders, columns, and foundations. Further, it is highly probable that the cost of the concrete flooring would have been considerably lessened. Without going into a series of tedious calculations, it would be impossible to suggest even an approximately correct monetary value for the saving that might have been effected in this way, but the amount would probably have to be reckoned in thousands rather than in hundreds of pounds.

Reinforced concrete has also been employed very largely in the flat and Mansard roofs of the building. As shown in *Fig.* 16 the general framing of the roofs was erected by the structural engineers, but the intermediate work was executed on the Columbian system. The frames for all the dormer windows were built up in a very simple manner with ribbed bars cut to required lengths, bent to shape, and interlocked by the insertion of bars through holes punched in the webs of other bars, the framework so formed being afterwards encased in concrete. Bars of the same type were employed for the reinforcement of the concrete roof slabs, the bars being attached by the aid of stirrups and anchors clipped or bolted to the main members. Operations in connection with the manipulation of the ribbed bars were much facilitated by the ingenious set of machinery provided by the Columbian Company for the execution of their work, without the necessity of any preliminary treatment in the shops.

All the concrete used in the floors, and roofs, and for the casing of girders and columns was made with destructor clinker as aggregate, the proportions adopted being 1 part of Portland cement, 2 parts of sand, and 4 parts of clinker. In some special cases the concrete was mixed by hand, but for the bulk of the work mixing machinery was employed.

The Ritz Hotel was erected from the designs and under the superintendence of Messrs. Mewes and Davis, architects, with the co-operation of Mr. John P. Bishop. The general building contractors were the Waring White Building Co., Ltd., by whom sub-contracts were let to Messrs. M. A. Potter and Co., structural engineers, the Columbian Fireproofing Co., Ltd., and other firms whose work does not come within the scope of this article. The Portland cement used both for floors, roofs and the encasing of the steel was that known as the Hilton Anderson Brand.



Failures in Reinforced Concrete and their Lessons.

THE COLLAPSE OF A THEATRICAL SCENERY STORE AT BERNE.

At the Seventh International Congress of Architects a resolution was adopted at the suggestion of Mr. Max Clarke, F.R.I.B.A., to the effect that failures with reinforced concrete be independently investigated. We have dealt with the resolution elsewhere, in our fourth issue, but, as already stated, we would repeat that we consider that reliable data as to failures must be of the greatest possible value to engineers, architects, and contractors alike, and even more so to the specialists connected with any work upon which there has been a failure. Only by full appreciation of any weakness in a system or method of execution is it possible to limit the risk of accident.—ED.

ONE of the most serious accidents which has yet occurred in connection with reinforced concrete construction was the collapse of a scenery store erected by the municipal authority of Berne, in Switzerland, which took place on August 23rd of last year, and in which several workmen were killed. In accordance with the excellent practice of the Swiss authorities in such cases (compare this journal, p. 265) an elaborate and detailed investigation of all the factors of the accident was carried out by Herr E. Elskes, of the Federal Railway, and Prof. F. Schüle, of the Zürich Polytechnic. The greater part of their report has appeared in the *Schweizerische Bauzeitung*, from which the following account is condensed:—

The building formed a block 50 metres (164 ft.) long and 13 m. (42 ft. 7 in.) wide, divided by transverse walls into three parts, a two-storied office building at one end and a store for scene cloths, with loft, at the other. (*Fig.* 1.) The middle section, to which the collapse was confined, formed a single large room, 21.9 m. (71 ft. 9 in.) long, intended for the storage of wings, and, therefore, extending through the whole height of the building, about 27 ft. The walls were of brick, while the floors and roof, on account of the special liability of such buildings to fire, were of reinforced concrete.

The plans were prepared by the architect of the theatre, Herr R. von Wurstemberger, with whom Herr O. Bolliger, Bridge Engineer of the Berne Railway Department, was associated so far as regards the reinforced concrete work.

In February, 1905, several firms engaged in this class of construction were invited to send in designs and estimates for the carrying out of this roof and floor work. The scheme of Messrs. Anselmier et Cie., with designs by H. Lossier, was accepted, although theirs was not the lowest tender. The two end portions of the building were first erected and roofed by the contractor, Herr Glauser, who next proceeded to build the front wall of the central portion, completing this part of the work on July 20th. (The back wall was the wall of the French church.) The reinforced concrete contractors then commenced the construction of the beams and roof, and the centering was in course of removal, 25 to 28 days after finishing the concreting, when the building collapsed.

The roof of this central portion was of the form shown in *Fig.* 2. Four beams, of 12.4 m. (40 ft. 8 in.) span and of the form shown, carried the whole weight. It will be seen that they rested at one end on the church wall, were horizontal for $\frac{5}{6}$ of their length, and were then bent to the profile of the Mansard roof, resting on the front wall at a point about 9 ft. 6 in. lower than the other bearing. The web of each beam was curved at the Mansard end, a point to which the authors of the report attach great importance. These main beams were connected by reinforced concrete joists 6 ft. 6 in. apart, to assist in carrying the 5-in. layer of concrete forming the roof. Four out of the five bays collapsed, the most easterly bay being the only one to remain in position. (See *Figs.* 3, 4 and 5.)

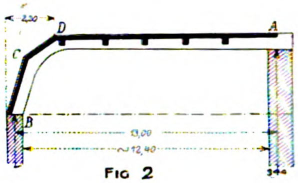


FIG 2

THE DESIGN.

The original design of February, 1905, for the roof-construction was accompanied by drawings and a statical computation. Considerable alterations were made in this, however, and the design of April, 1905, differed from the original one in important particulars. The new design and statical computations were not submitted to any expert for approval.

The height of the main beams was reduced from 75 cm. (30 in.) to 65 cm. (26 in.), the distance between the beams being at the same time increased from 6 ft. 6 in. to 13 ft. and 15 ft. 6 in. alternately—that is, more than doubled. This was taken into account in the statical calculation, but insufficiently; the reinforcement was increased, although the thickness of the part subjected to compression remained the same. The new calculation assumed a much greater width for the plate of the **T**-beam. It is not legitimate, when the beams are so far apart, to assume that the whole of the plate between them contributes to the compressive strength, and the most probable value for the effective width is $\frac{2}{3}$ of the actual width. Even with this unduly favourable assumption, the design led to an average pressure at the middle point of each beam of 36 kg./cm. , as against 28 kg./cm.^{2} in the design approved in February. And this does not take into account the bending of the plate. The authors of the report, taking these factors into consideration, arrive at a maximum stress of 47 to 69 kg./cm^2, a figure which might be increased 15 per cent. by a load of snow. Such a stress is dangerous when the concrete is fresh. Errors in the calculation of the shearing stress are also pointed out.

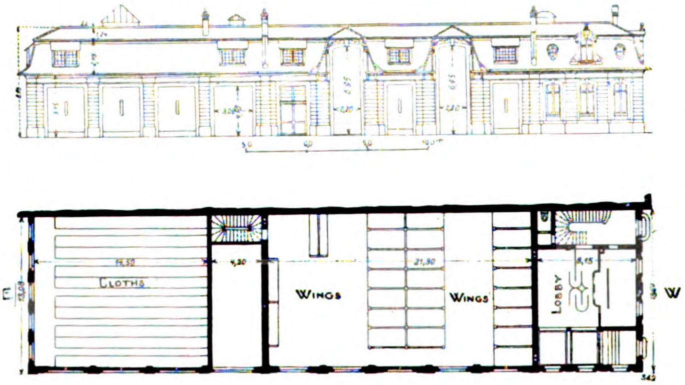


FIG 1

PLAN AND ELEVATION OF THE SCENERY STORE.

The design of the bent portions of the beams (*Fig.* 2) is seriously defective. Only the bend at **C** is provided with special reinforcement; the bend at **D**, which is subjected to much more severe stresses, is quite insufficiently reinforced. The stresses at this point were not considered in the statical calculation, and a calculation by Herr Lossier, made subsequently to the collapse, and giving a safe stress, is shown to be based on a series of unduly favourable assumptions. The great weakening of the roof by the numerous dormer windows and other openings, and by the insertion of wooden blocks and laths into the concrete, was not taken into account in the statical calculation.

The bearing of the roof beams on the front wall was of the form shown in *Fig.* 6, Herr Lossier having adopted this instead of the roller bearing originally proposed. The form adopted is considered to exert an undue outward thrust on the wall.

THE EXECUTION OF THE WORK.

The contractor for the brickwork carried out his part of the construction satisfactorily, and no discredit attaches to him. The reinforced concrete contractors, Messrs. Anselmier and Co., are, however, blamed on several points. Without the consent of Herr Lossier, the junctions of the webs of the beams with the under surface of the concrete plate were made sharp, instead of being rounded off, as shown in the drawings. The long vertical poles used to support the centering were insufficiently supported sideways, so that when some of the supports were removed, the others were unable to bear the increased load without bending, as is clearly shown in the photographs. The Swiss Provisional Rules prescribe a minimum interval of 30 days before removing the centering of long beams; in this case the centering of the two western beams was removed after 25 days, although the thick covering of cement and gravel on the roof was a reason for allowing more than the minimum interval. Another serious error was that of ignoring completely the steel rocking bearings (*Fig.* 6), which were allowed to rust, and were then built into the concrete. No communications appear to have taken place between the contractors and the designer on this point.

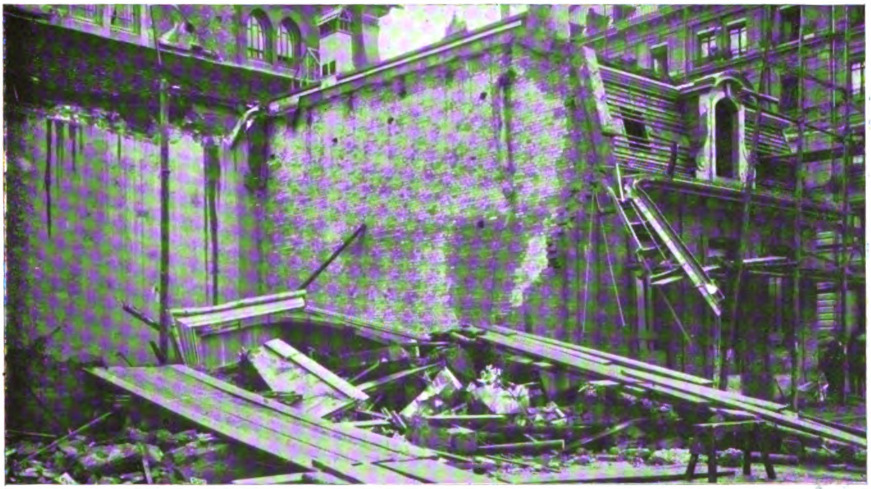


FIG. 3. VIEW AFTER COLLAPSE, LOOKING WEST.

Nothing was specified in the contract as to the nature of the materials to be used, this being left entirely to the contractors. The usual mixture of sand, washed gravel, and St. Sulpice cement was employed, but no tests of any kind were made. Subsequent tests made by the authors of the report at the Zürich Testing Station have shown that the cement was of good quality, but tests made on cubes of concrete cut from the beams after the accident gave low results, probably owing to the concrete having been mixed too wet, in order to facilitate ramming.

The supervision of the work was insufficient, and it is considered that the municipal authority, as building owner, should have provided such supervision, and should also have specified the materials to be used and to have required tests to be made.

CONCLUSIONS.

The authors conclude that reinforced concrete was a suitable material for the structure. They also consider that the blame for the disaster is not to be attributed to culpable neglect on the part of any person concerned. The accident was due, rather, to a combination of causes, which could have been avoided by a more rigid control. These causes are enumerated as follows:—

(*a*) Unduly large stresses in the structure, particularly in the middle of the beams, at the upper edge of the Mansard roof, and at the junction of web and plate.

(*b*) An unsuitable arrangement at the bearing of the beams on the front wall, causing an outward thrust on the latter.

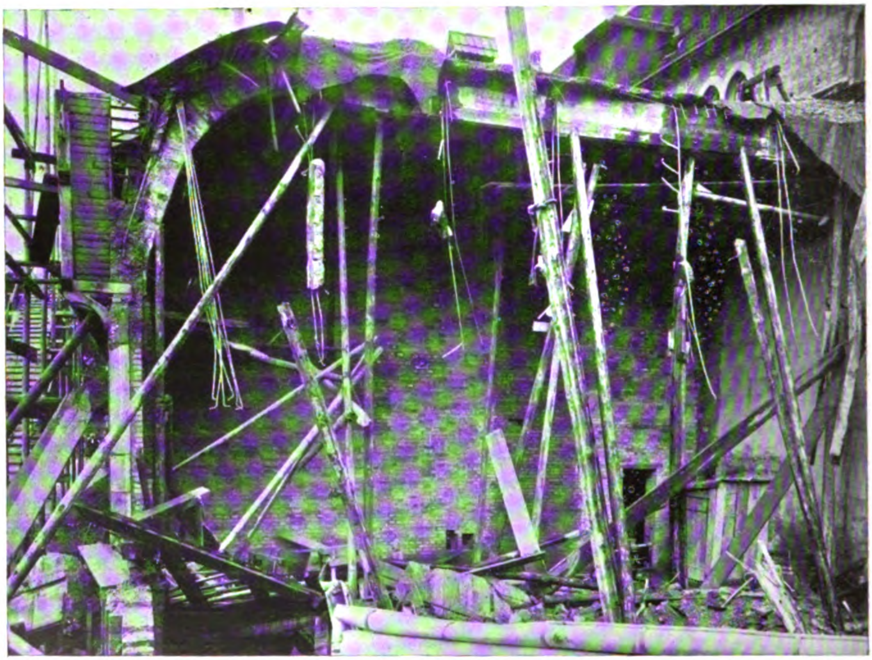


FIG. 4. VIEW AFTER COLLAPSE, LOOKING EAST.

(*c*) Weakening of the already weak roof by insertion of wooden laths.

(*d*) Carelessness in the removal of the centering, the concrete being insufficiently hardened, and the covering of the roof with a heavy cement layer being carried out too soon.

(*e*) Weakness of the supports of the centering, so that when some of the supports were removed the remainder were unduly loaded.

The following were indirectly contributory causes:—

(*a*) Insufficient control of the design, which departed from that originally approved in important particulars.

(*b*) Failure to supply a statical calculation, which would have apprised the building authority of the altered conditions and loading.

(*c*) Omission of the architect to demand such a calculation.

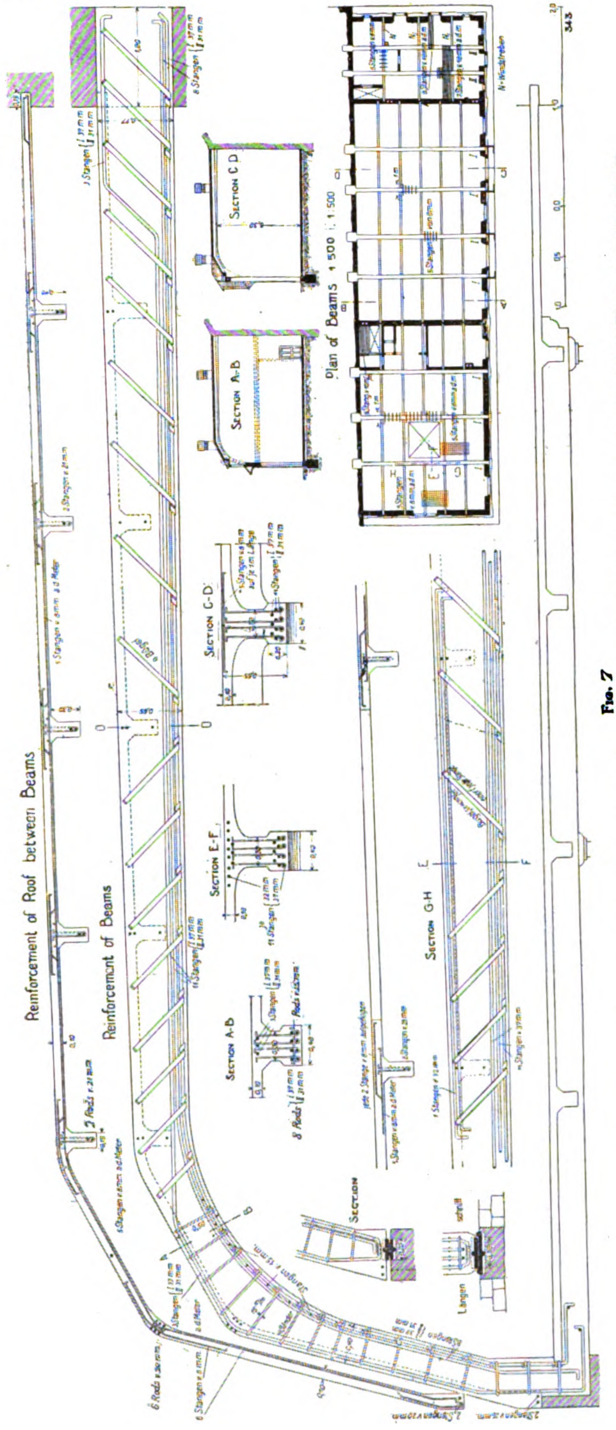


FIG. 7. THEATRICAL SCENERY STORE AT BERNE: THE DETAILS OF CONSTRUCTION AND OF THE REINFORCEMENT. (From a German Working Drawing).

(*d*) Insufficient communication between the designer and the contractors, whereby the designs were not understood, and dangerous alterations were made in them by the contractors.

(*e*) Omission of any specification of the armoured concrete in the contract.

A SUBSEQUENT ARGUMENT ARISING OUT OF THE REPORT.

IN consequence of Messrs. Elskes and Schüle's report on the collapse of the theatrical scenery store at Berne, which is here presented, Herr Henry Lossier, the engineer responsible for the reinforced concrete construction, has addressed an important letter to the *Schweizerische Bauzeitung*, of September 22nd, which we summarise below.

Herr Lossier remarks that the subject is now under consideration by a legal tribunal in Berne, and also demands a conference of experts to examine the question.

As regards the breadth of flange to be regarded as contributing to the strength of a beam, it is urged that, although our knowledge of the subject is very imperfect, the writer's formula,

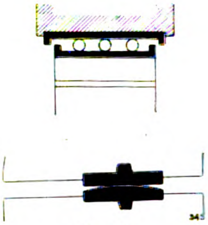


Fig. 6.

deduced from Considère's experiments, has greater justification than that assumed by Messrs. Elskes and Schüle. The stresses considered by the latter to exist in the concrete of the roof are stated to be greatly in excess of those which could actually occur, and the same is held to be the case as regards the stresses at the angle of the roof beams.

The most important portion of the letter consists in the description of a test carried out at Lausanne on March 23rd, 1906, in the presence of Professors Bosset and Paris, on a roof truss similar to those used in the collapsed building, constructed to ½-in. scale. This truss was loaded with sacks of sand to an extent equivalent to 1⅔ times the amount of the total load on the day of the accident, a deflection of only 2·4 millimetres being produced, and no cracks being developed in the structure. Professors Bosset and Paris consider this test to justify Herr Lossier's design. M. Considère, Prof. Guidi, of Turin, and Prof. Melan, of Prague, express the opinion that the tests on the half-scale model allow valid conclusions to be drawn as to the strength of the actual structure.

In a short reply, Messrs. Elskes and Schüle decline to discuss the details of the question at present, the matter being ***sub judice***.

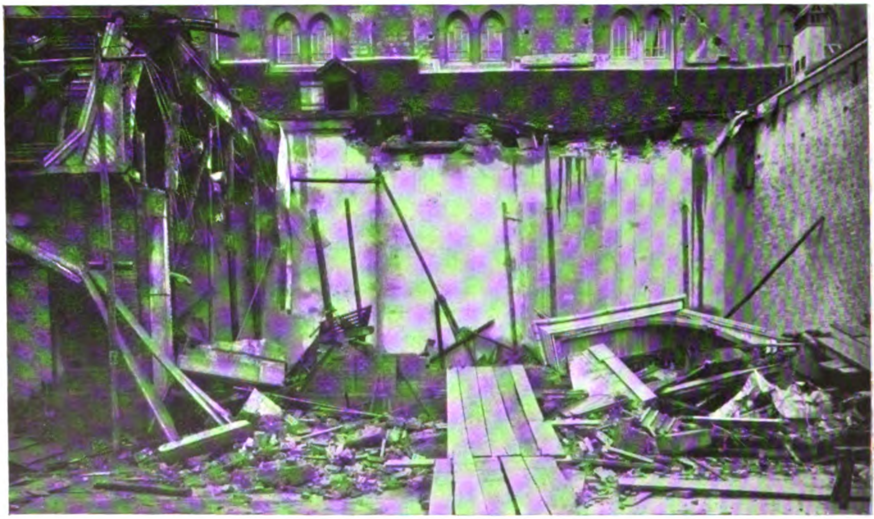
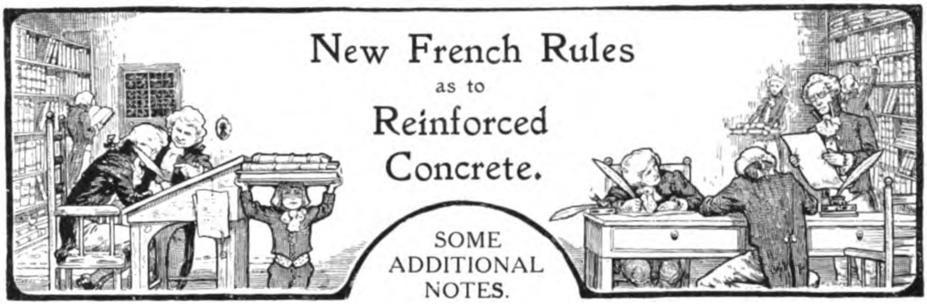


Fig. 5. View after Collapse.



New French Rules as to Reinforced Concrete.

SOME ADDITIONAL NOTES.

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In our previous issue we presented a specially-prepared translation of the important Instructions—i.e., Rules on Reinforced Concrete—which were at the time just about to be issued by the French Ministry of Public Works, together with an explanatory Circular of the highest possible interest. These Rules were actually signed on the 20th of October, and found publicity in the French Press after the official translation had appeared in our columns.

We attach the very greatest importance to the Rules and Circular in question, and we thus add some particulars as to a special report that has been officially issued in connection with these Rules in France, together with some slight modifications of the translation which have been noticed upon comparing the original as issued with our translation.

ON the 20th October, 1906, the French Ministry of Public Works signed the new Rules as to reinforced concrete, of which a specially prepared translation was presented in our November issue. In the previous article we dealt with the "Instructions" and the "Explanatory Circular," but said nothing relative to the "Report of the Commission" appointed by the Conseil Général des Ponts et Chaussées. As this report is of the utmost importance we now give a summary of its contents, and two notes upon modifications made in the text of the "Instructions" and "Explanatory Circular."

REPORT OF THE COMMISSION.

Although the valuable qualities of reinforced concrete structures are every day becoming more recognised, we know but imperfectly their laws of resistance, and the more we get to understand of the matter the more we find points left in the dark. It is not easy, therefore, to give sufficient precision to the Instructions without closing the door open to improvements.

The Commission used the word "Instructions" for the reason that, whilst involving for the "Ingénieurs des Ponts et Chaussées" the same binding character, it does not imply the same degree of immutability as the term "Regulations." It is, in fact, quite conceivable that the practical knowledge acquired in the contractor's yard, and in the laboratory, as well as further progress in theory, may change even the most up-to-date opinions, and necessitate modifications in the Instructions.

Theoretically, the value m would be the ratio of the moduli of elasticity of the metal and of the concrete, and which the experiments of MM. Rabut and Mesnager show to be equal to 10, although the value 15 has been adopted in Switzerland as well as by several French and German authors. The last-mentioned value imputes to the metal a greater influence, and to the concrete a lesser one, than that actually exerted, so that the concrete would bear greater stresses than those indicated by calculations.

The innovation in the Instructions consists in the assumption that m has not an immutable value, but a value depending upon the relative arrangement of the longitudinal and transverse or oblique reinforcement. They admit that m may vary from 8 to 15 according to the more or less combination of these reinforcements. Investigation into the value of this coefficient was made by five series of tests upon concrete prisms of square section, measuring 25 × 25 centimetres by one metre high, with different reinforcements, the tests being very accurately conducted by Professor Bach, and carried to the point of rupture.

We make here a comparison between the practical breaking loads thus determined, and the working stresses resulting from:

1°—Formulæ to which is applied a coefficient m constant and equal to 15.

2°—Formulæ to which is applied a coefficient m varying from 8 to 15 in accordance with the rules indicated in the Instructions, and with interpolations made in an approximate way between the different limits allowed for the stresses by article 5 and expressed by the function

$$1+m'\frac{V'}{V},$$

in which is inserted the value m' indicated by the Instructions.

In the case of the prisms tested the sectional area was:

$$\Omega=25\times 25=625\ cm^2$$

and the volume of the ties was:

$$V'=62,\ 645\ cm^3$$

As shown in *Fig.* 6, the prisms had a square section A B C D, side=250 millimetres; they were reinforced with four longitudinal bars distant 180 millimetres from centre to centre, and having diameters varying from 15 to 30 millimetres.

The longitudinal bars were connected one to another by double ties on the four sides of a square, all of these ties having the diameter of 7 millimetres.

The spacing of the transverse reinforcement parallel to the axis of the prism varied from 25 to 6.25 centimetres.

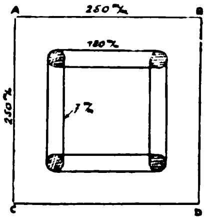

FIG. 6.

The results of the five series of tests are summarised in Table I.

TABLE I.

No. of Experiment.	Diameter (d) of the Longitudinal Reinforcement.	Spacing of the Transverse Reinforcement.	Average Value of the Breaking Load.	Sectional Area of the Longitudinal Reinforcement $w=4\frac{\pi d^2}{400}$ cm².
	mm.	cm.	Kg. per cm².	cm².
1	15 mm.	25·00 cm.	161 Kg.	7·1
2	15	12·50	177	7·1
3	15	6·25	205	7·1
4	20	25·00	170	12·6
5	30	25·00	100	28·3
(1)	(2)	(3)	(4)	(5)

The breaking load of the prism in plain concrete was found to be 141·95 Kg., and the breaking load of a cubic metre of the same concrete was found to be 175·95 Kg.

Assuming $m=15$, and R_c being the safe stress allowed for concrete, the total load (N) the reinforced concrete would be capable of supporting is

$$N=R_c\ (625+15w)\ \ldots\ldots\ldots\ldots\ \text{(A)}$$

Taking $R_c=35$ Kilogrammes, in accordance with the German rules, we find:

$$N=35\ (625+15w)\ \ldots\ldots\ldots\ldots\ \text{(A')}$$

TABLE II.

No. of Experiment.	$\frac{15w}{cm^2}$	625+15*w*.	N. Kg.	$\frac{N}{625}$	Breaking Loads.	Effective Factor of Safety.
1	106	731	25·585	40·9	168	4·1
2	106	731	25·585	40·9	177	4·3
3	106	731	25·585	40·9	205	5·0
4	189	814	28·490	48·6	170	3·7
5	424	1049	36·715	58·7	190	3·2
(1)	(2)	(3)	(4)	(5)	(6)	(7)

In Table II. column 5 gives the theoretical load per square centimetre, supported by the concrete of the prism, and column 6, reproducing column 4 of Table I., gives the corresponding effective breaking loads. Dividing the figures of column 6 by those of column 5, we get in every case the effective factor of safety, the variations of which between 5 and 3.2 appear considerable; and we see that formula (A), corresponding to a constant value of *m*, may cause grave miscalculation.

Assuming, however, the value of *m* to be variable, and making the same calculations in accordance with the instructions, we obtain by interpolation the figures given in Table III.

TABLE III.

No. of Experiment	*w*	$\frac{m\,w}{c\,m^2}$	625+*m w*	Spacing of the Transverse Reinforcement.	*m'*	$\frac{V'}{V}$	$R_c - 50$ $4m'\frac{V'}{V}$	N	$\frac{N}{625}$	Effective Factor of Safety.
1	10	71	696	0^m·25	8	·00401	51·6	35·913	57·4	2·9
2	12	85	710	,, 125	12	·00802	54·8	38·908	62·3	2·8
3	15	106	731	,, 0625	15	·01604	62·00	55·322	72·5	2·8
4	9	113	738	,, 25	8	·00401	51·6	48·080	60·9	2·8
5	8	226	851	,, 52	8	·00400	51·6	43·911	70·2	2·7
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)

Again, taking the permissible stress at 50Kg. instead of 35Kg. allowed in Germany, and according to article 5, and amplifying this stress in the ratio expressed by the coefficient $\left(1+m'\frac{V'}{V}\right)$, we get:

$$R_c = 50\left(1+m'\frac{V'}{V}\right) \quad \ldots\ldots\ldots\ldots \quad (B)$$

From the values of *m* applied in Table III. result the loads (N) that the prism is able to support. Thus:

$$N = R_c(625+m\omega) \quad \ldots\ldots\ldots\ldots \quad (B')$$

The figures of column 9 are given by formula (B'); the figures of column 11 are obtained by dividing the figures of column 10 into the breaking loads (Table I., column 4); and we see that as the effective factor of safety is remarkably constant, we may be bolder in the use of the ultimate theoretical safe stresses allowed in the Instructions.

MODIFICATIONS OF THE "INSTRUCTIONS" AND "EXPLANATORY CIRCULAR."

The only modification made by the Conseil Général des Ponts et Chaussées in the Instructions is the following:

Safe Working Stresses (Section I, Clause B, par. 4[*]). Instead of $^4/_7$ read 0.28.

In the Explanatory Circular there are two modifications, the first being merely a consequence of the modified safe working stress for concrete, as follows:

Safe Working Stresses (Section I, Clause B, par. 4[†]).

Instead of	45.7	51.4	57.1 Kg.
Read .	44.8	50.4	56 Kg.

In Section II. of the Explanatory Circular, Article 12[‡] has been modified as follows:

Compression with Flexure.

When flexure is anticipated in members subject to compression we may employ Rankine's rule, expressed by the following *inequality*:

$$\frac{N}{\Omega}\left(1+\frac{Kl^2}{10000r^2}\right) < R_c \quad . \ . \ . \ . \quad (29)$$

Where N is the compressive stress, and when N varies considerably from one end to the other of the member, the value for the section at equal distances from the ends is to be taken. l is the length of the member; r is the least radius of gyration of the cross section, which, in the common case of a symmetrical member, is to be found either in the direction of the axis of symmetry, or perpendicular to that direction; R_c is the safe working stress allowed for concrete by article 4; K is a numerical coefficient depending upon the manner in which the ends of the member are fixed, and having the values given in Table A.[§]

When the compressed member is of great length the unit in formula (29) may be omitted from the quantity $\left(1+\frac{Kl^2}{10000r^2}\right)$, and we may simplify the inequality expressing the degree of stability as follows:

$$\frac{N}{\Omega}\ \frac{Kl^2}{10000r^2} < R_c$$

or:

$$N < \frac{10000\Omega r^2}{Kl^2}\ R_c \quad . \ . \ . \ . \ . \quad (30)$$

The average value of R_c is about 50 Kg. per square centimetre. The modulus of longitudinal elasticity of the concrete being generally the tenth part of the corresponding modulus of steel we get:

$$E_c = 2 \times 10^5.$$

Then the product $10000R_c$ may be taken approximately equal to $\frac{\pi^2 E_c}{4}$, and the condition (30) may be written:—

$$N < \frac{\pi^2 \Omega r^2}{4Kl^2} \times E_c \quad . \ . \ . \ . \ . \quad (31)$$

That is Euler's formula if we take 4 as the factor of safety; therefore, the indications given by Euler's formula agree with those of Rankine's rule for long members.

If the member subjected to a compressive stress is acted on besides, by a bending moment of some importance as in the case of an eccentric load, or of wind pressure, the condition of stability expressed by the inequality (29) is to be completed by the introduction of the value of the maximum compressive working stress resulting in the middle section from the bending moment M, which is expressed as

$$\frac{M}{I}\ \text{(formula 5); or}\ \frac{Nv_0v}{\Omega r^2}\ \text{(formula 11).}$$

Therefore Rankine's rule becomes one or the other of the following inequalities:

$$\frac{N}{\Omega}\left(1+\frac{Kl^2}{10000r^2}\right)+\frac{Mv}{I} < R_c \quad . \ . \ . \quad (32)$$

$$\frac{N}{\Omega}\left(1+\frac{Kl^2}{10000r^2}+\frac{V_0V}{r^2}\right) < R_c \quad . \ . \ . \quad (33)$$

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[*] *Concrete and Constructional Engineering*, p. 332.

[†] *Ibid.*, p. 334, col. 2, line 18.

[‡] *Ibid.*, p. 340.

[§] *Ibid.*, p. 340.

MEMORANDA.

Memoranda and News Items are presented under this heading, with occasional editorial comment. Authentic news will be welcome.—ED.

The Milan International Exhibition.—Whilst British constructional engineering, and reinforced concrete in particular, can scarcely be said to have been properly represented at the Milan International Exhibition, there were a number of exhibits originating from France, of which several obtained well-merited awards. Some exhibits we would particularly notice were shown by M. Considère, of Paris—namely, a number of specimens of armoured concrete, together with photographs, shown with a view to demonstrating his system; and this exhibit created considerable interest. M. Considère has now established a London agency at 3, Victoria Street, Westminster, London.

* * *

A Concrete Arch of 230 ft. Clear Span.—An arch of this important span is being constructed in the Walnut Lanes Bridge at Philadelphia. When completed we believe it will be the principal arch of its kind in reinforced concrete existing. Its rise is 73 ft. The bridge is designed to carry ordinary road traffic with 60 ft. roadway.

* * *

"The Cement Age." We should like to call special attention to recent issues of *The Cement Age*, our American Contemporary, which, in excellence of interest, were of high merit. It is edited by Mr. Robert W. Leslie, the well-known cement manufacturer, and an Associate of the American Institute of Civil Engineers.

* * *

Trade Announcements.—The Patent Indented Steel Bar Company's system of steel reinforcement is being extensively used in the floors of the Waldorf Hotel and the Strand improvement. The Indented Bars are also being employed in the foundations for the machinery of the *Morning Post*. In Scotland the method is being adopted by the Coventry Ordnance Company.

The Associated Portland Cement Manufacturers inform us that their well-known "J. B. White and Brothers" Brand of Portland cement has been employed to the extent of 17,000 tons in the new War Office building in Whitehall, which has just been completed.

Messrs. D. J. Sullivan and Co. inform us that they are carrying out works at Southampton with the Kahn Bar of the Trussed Concrete Steel Co.

NEW WORKS IN CONCRETE

AT HOME AND ABROAD.

Under this heading reliable information will be presented of new works in course or construction or completed, and the examples selected will be from all parts of the world. It is not the intention to describe these works in detail, but rather to indicate their existence and illustrate their primary features, at the most explaining the idea which served as a basis for the design.—ED.

EAST BOSTON TUNNEL.

WE are presenting herewith a cross-section of the East Boston Tunnel under the Harbour, as illustrating a concrete tunnel of 23 ft. width for a double line of rails, which, after two years' trial, has proved to be a most successful example of tunnel construction.

The length is 1¼ miles, of which nearly one mile is actually underneath Boston Harbour. The top rail in the tunnel is about 77 ft. below the water level. The leakage in the tunnel for the total length of 1¼ miles, is 7 gallons per minute.

The point of interest to engineers may be found in the arrangement of the ventilation duct at the top of the tunnel, which is separated from the body of the tunnel by a ceiling of expanded metal lathing filled in with mortar

(From an article by E. S. Larned, C.E., in the "Cement Age," U S A.)

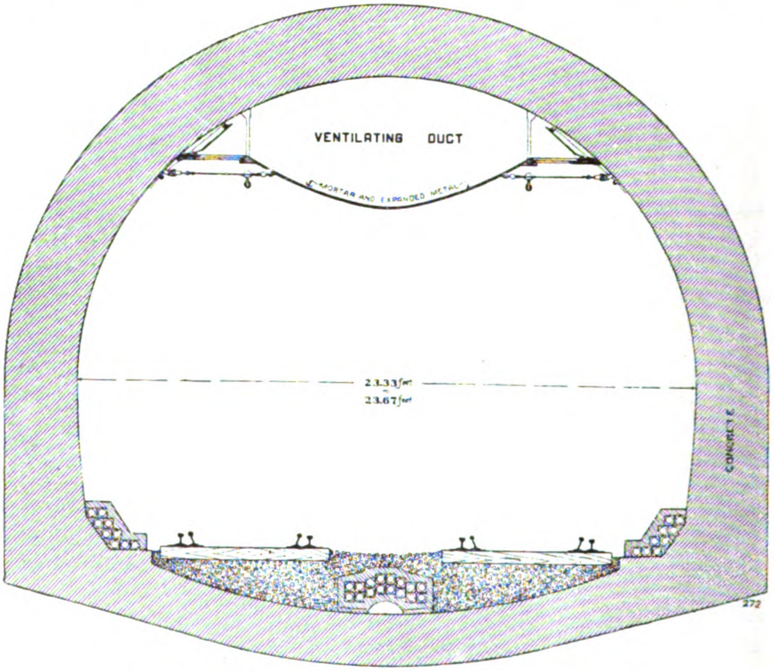


FIG. 1. EAST BOSTON TUNNEL, U.S.A.: CROSS SECTION.

BUSH TERMINAL WAREHOUSES, U.S.A.

THE Bush Terminal Warehouses at Brooklyn, New York, U.S.A., were referred to at considerable length in a paper read before the International Congress of Architects, and to give some idea of their extent we are presenting herewith a view of one of the blocks of these warehouses nearing completion.

In this building a "unit" system of reinforcement was applied, which proved both effective and economical, and not liable to derangement during construction, which is a matter of the utmost importance where fire-resistance is particularly aimed at. All columns built in reinforced concrete were further protected by a coating of cinder concrete.

It is pleasant to observe that the American insurance companies fully appreciated the care taken to design the reinforced concrete in a manner suitable for purposes of fire-resistance, a feature all too frequently overlooked in the haphazard application of this material without a due regard to the proper protection of the metal work, and the selection of the concrete aggregate.

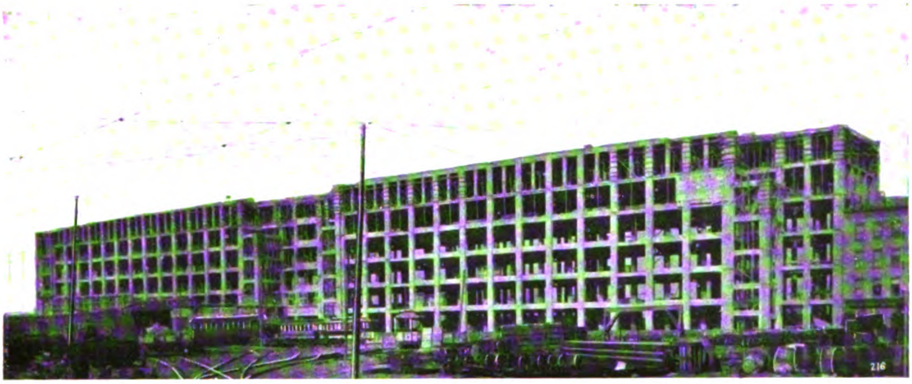


FIG. 2. BUSH TERMINAL WAREHOUSES, U.S.A.

REINFORCED CONCRETE CEMENT WAREHOUSE.

THE Associated Portland Cement Manufacturers, Ltd., have been extending their warehouses at Grosvenor Road, Pimlico, and have adopted for their construction reinforced concrete on the Hennebique system, the Portland cement used being of the "Nine Elms Brand."

We produce a general view of the buildings taken from the river, and also one showing the floor of the interior, where the nature of the heavy loads of cement to be carried, partly in sacks and partly in bulk, has been an important factor in the design. The question of the floor has attracted attention, and it may be of considerable interest to observe the results of the tests undertaken by Mr. L. G. Mouchel, the general agent for the Hennebique system in Great Britain, and the following is stated by him to have been the results of these tests:—

The portion of the floor tested measured 14 ft. long by 10 ft. wide, the clear span of the main supporting beam being 16 ft.

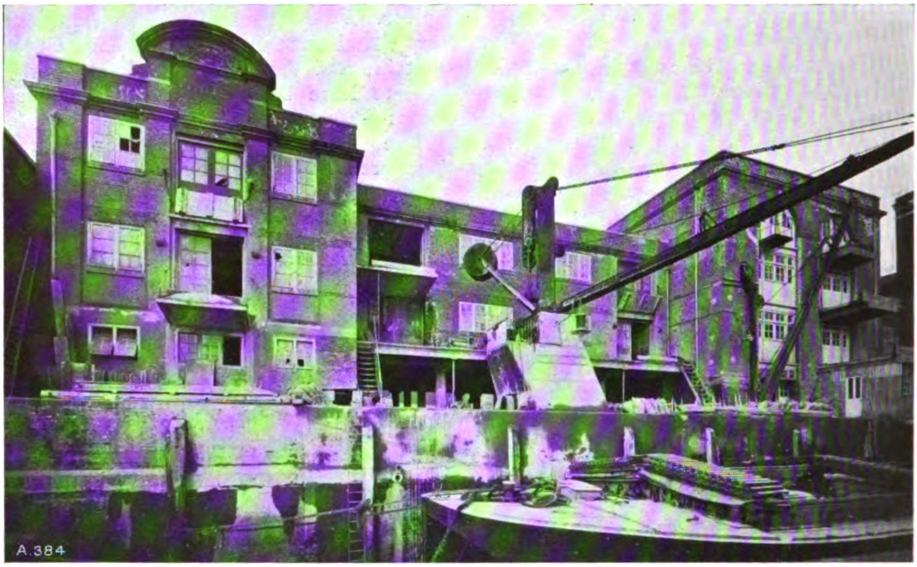
Before any load was placed on the floor three instruments for measuring deflection were adjusted beneath the main beam, Nos. 1 and 3 near the supports and No. 2 at the centre. The datum readings were then as follows:—

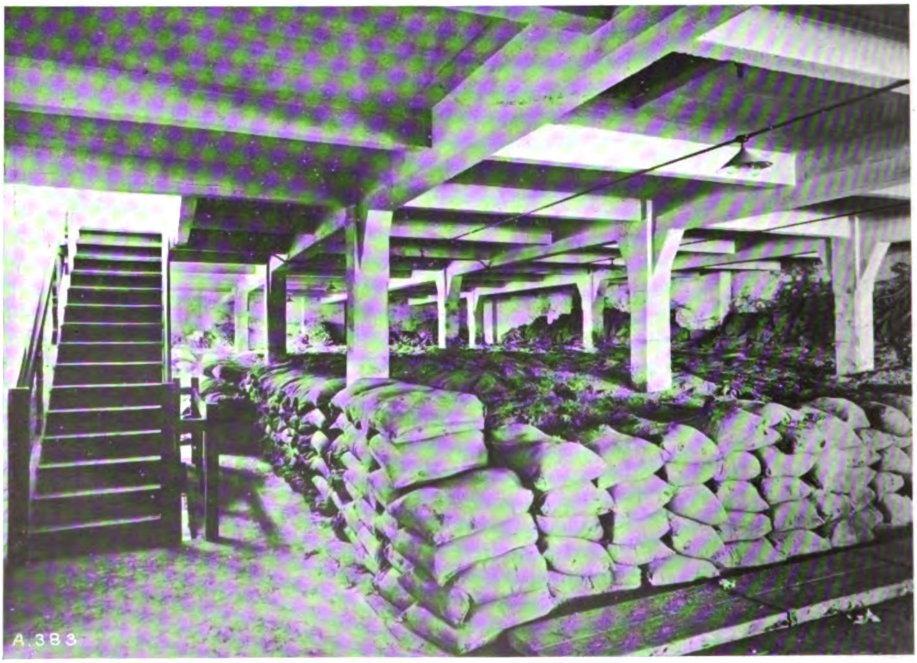
Instrument No.	1	0.9 millimetre.
,, ,,	2	0.8 ,,
,, ,,	3	1.2 ,,

At 2 p.m. loading was commenced, the material used being Portland cement in bags, each containing 200 lbs. The full test load comprised 462 bags of cement equal to the total load of 42 tons, or 6 cwt. per sq. ft. At 3.30, while the floor was still under this load, the three instruments gave the following results:—

Instrument No.	Test Reading.	Datum Reading.	Deflection.	
	MM.	MM.	MM.	M.
1.	1.5	0.9	0.6	0.0236
2.	3.0	0.8	2.3	0.0905
3	1.8	1.2	0.6	0.0236

As the clear span of the main beam is 16 ft., the maximum deflection of 0·0905 is only $\frac{1}{2121}$ of the span, or about two-sevenths the proportion of $\frac{1}{600}$ specified by the architect.





Figs. 3 & 4.
Reinforced Concrete Cement Warehouse, Grosvenor Road, London.

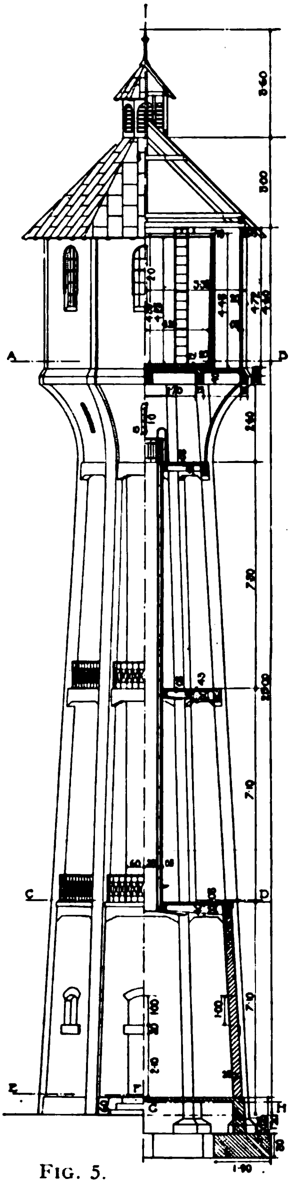


FIG. 5.

NEW REINFORCED CONCRETE WATER TOWER AT OBER SCHÖNEWEIDE.

NEW WORKS IN GERMANY.

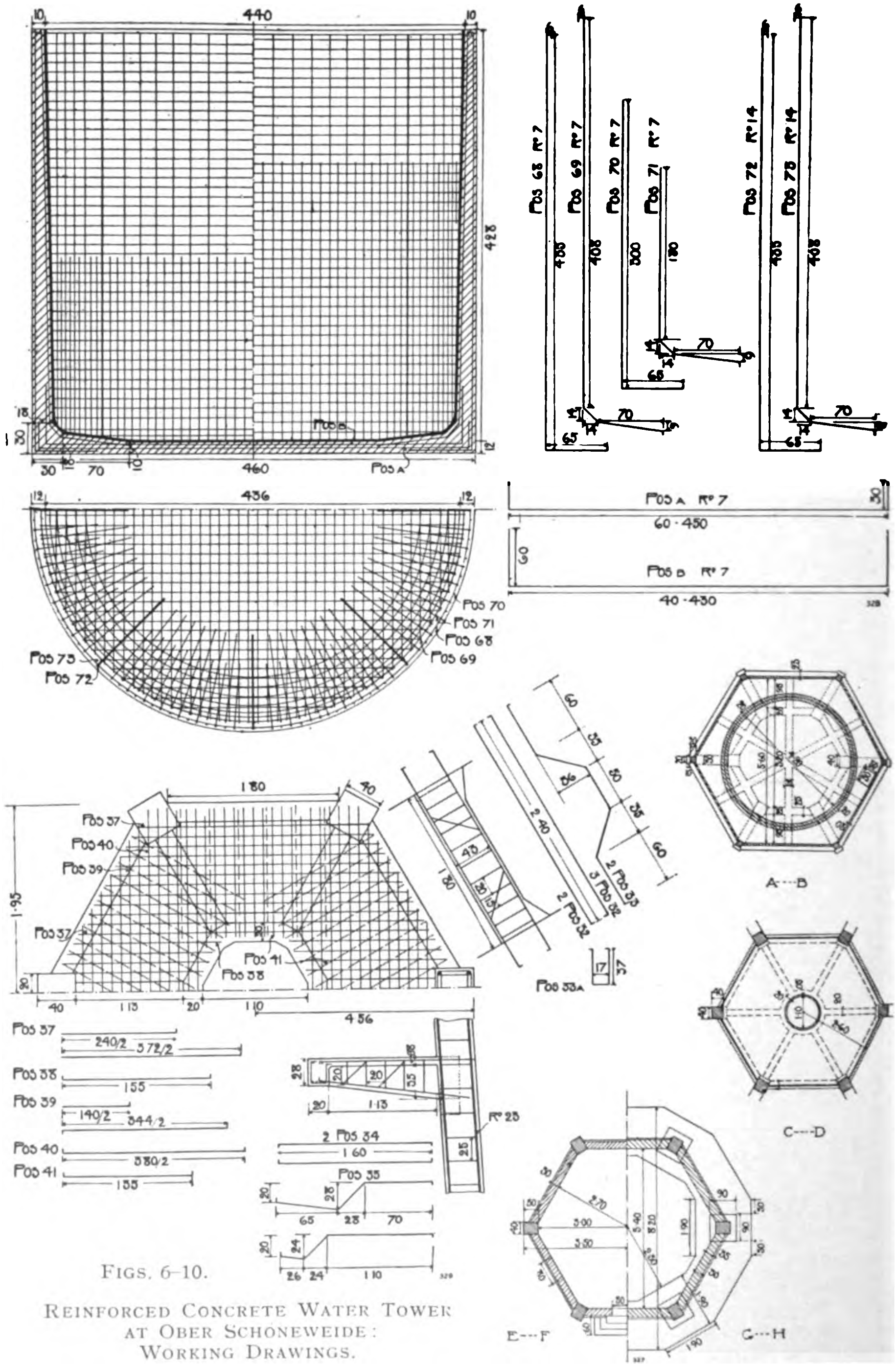
The following examples of such works are of recent date and have been kindly placed at our disposal for the purpose by the originators, Messrs. Wayss and Freytag, Ltd., of Berlin.

The water tower at Ober Schöneweide, near Berlin, is one of the first executed by Messrs. Wayss & Freytag according to the Ministerial Regulations of April 16th, 1904. The cylindrical container is 4·2 metres in diameter and 4·5 inches in height, and holds about 55 cubic metres (72 cubic yards) of water. It rests on a platform which is carried by 6 rectangular columns 24 metres in height and of 60×60 cm. cross section. The wall of the container is 10 cm. thick at its upper edge and 20 cm. at its junction with the bottom, which is 12 cm. thick. The stand-pipe is 1·10 metres in diameter, and has sides 5 cm. thick. The wind pressure was calculated as 150 kg./m.², or about 30 lbs. per square foot, normal to the direction of the wind. The cost of the structure, which was completed in 1906, amounted to M.150,000 (about £7,500). The annexed diagrams (*Figs.* 5 to 10) illustrate the general construction of the tower, and the reinforcement of the platform and its container.

The factory building of Messrs. Caspary, of Marienfeld, near Berlin, illustrated by two diagrams (*Figs.* 11 and 12), occupies an area of over 1,200 sq. metres (about 1,400 sq. yards), and is constructed completely in reinforced concrete. The floors are calculated to carry a working load of 500 kg./m.² (about 100 lbs. per sq. foot). It will be seen from the drawings that the reinforcing rods have no variations of section to give greater adhesion. The figures in the diagrams give the lengths in metres, the sectional area of the concrete in centimetres, and the thickness of the metal in millimetres.

As it may be of interest to know the working loads permitted by the building authority in Berlin, the principal data may be given here. The authority requires it to be shown that the construction fulfils the conditions of the statical rules when the following minimum values of the working load are inserted in the calculations:—

Floors of dwelling houses ...	250 kg./cm.²,	or	50 lb.	per sq. ft
Business premises	400	,,	80	,,
Granaries	460	,,	95	,,
Libraries	500	,,	100	,,



FIGS. 6–10.

REINFORCED CONCRETE WATER TOWER AT OBER SCHONEWEIDE: WORKING DRAWINGS.

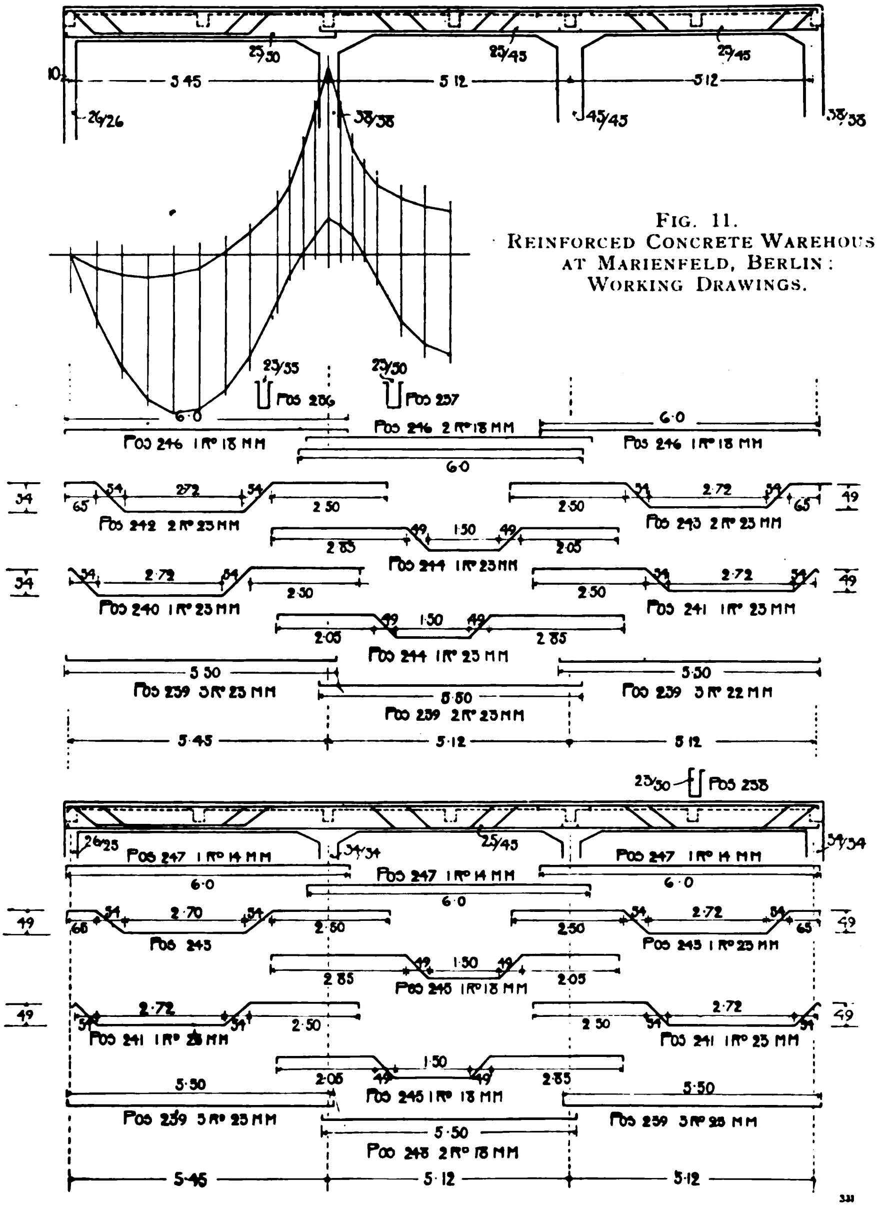


FIG. 11.
REINFORCED CONCRETE WAREHOUSE AT MARIENFELD, BERLIN: WORKING DRAWINGS.

THE STRONG ROOM AT THE MONT DE PIETÉ, MILAN.

REINFORCED concrete lends itself particularly well to application in strong rooms, vaults, and similar cellars where every possible precaution has to be taken, not only in respect to fire, but also in respect to theft. The grillage of the metal rods is particularly inconvenient for the burglar in cases where ordinary concrete would probably succumb to his efforts.

The best example of this kind of work of which we know is that of the safe

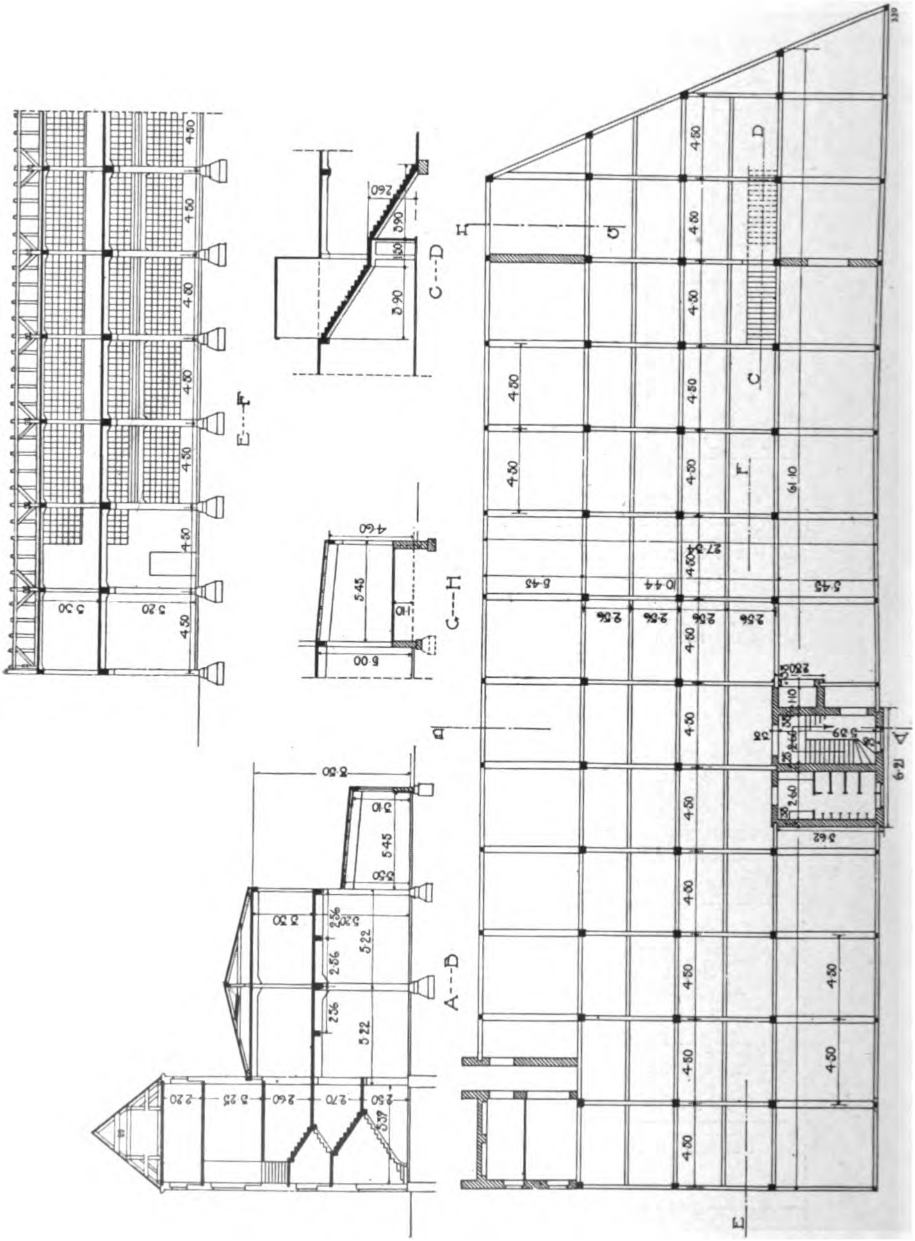


FIG. 12. REINFORCED CONCRETE WAREHOUSE AT MARIENFELD, BERLIN: GENERAL PLAN AND SECTION.

deposit vaults at the Mont de Pieté, Milan, a building which is second to none in both construction and equipment.

We present an illustration of the principal safe deposit vault in *Fig.* 14, and we also show three views explanatory of the construction of the walling and the flooring, and indicative of the general methods of building the vault. It will be easily seen from the details of

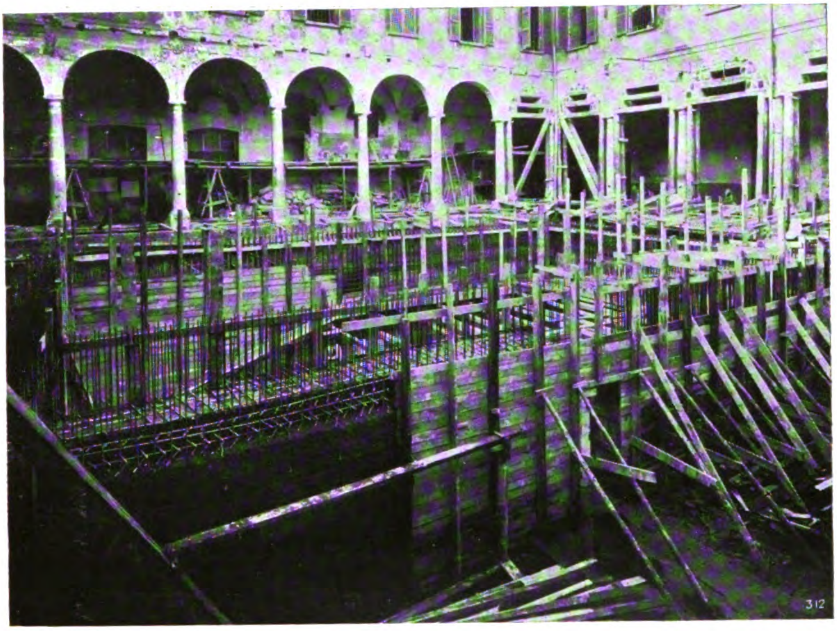


FIG. 13. THE REINFORCED CONCRETE SAFE DEPOSIT VAULT IN COURSE OF CONSTRUCTION.

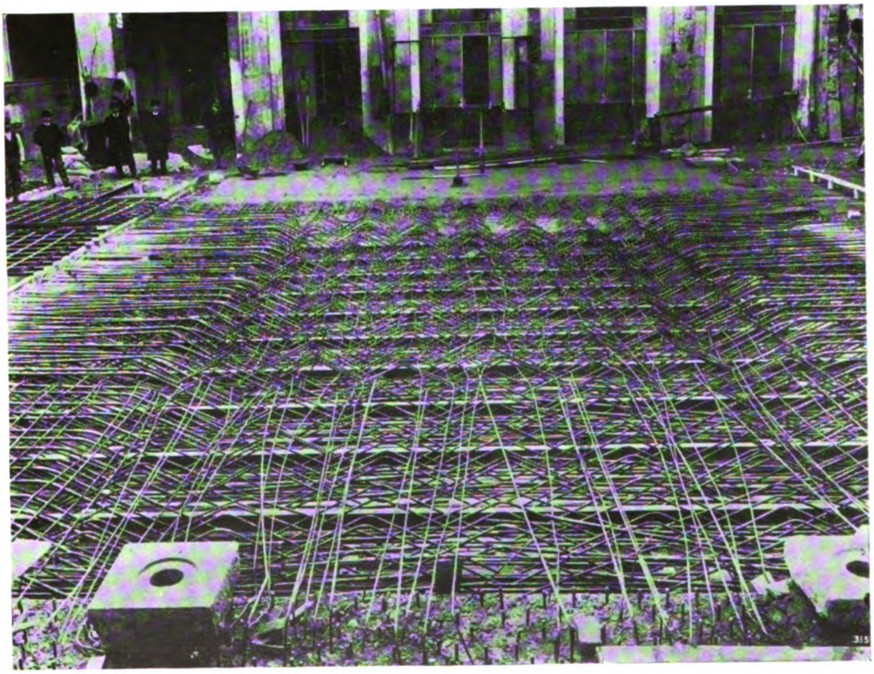


FIG 14. REINFORCED FLOOR OVER SAFE DEPOSIT VAULTS IN COURSE OF CONSTRUCTION.

THE MONT DE PIÉTÉ: MILAN.

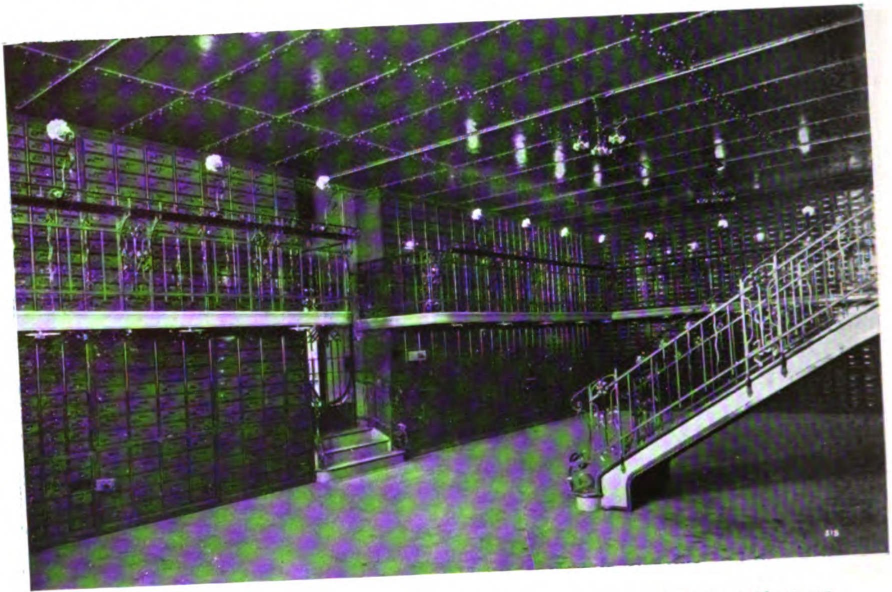


FIG. 15. MONT DE PIÉTÉ, MILAN: INTERIOR OF SAFE DEPOSIT VAULTS.

the wall construction how difficult and inconvenient it would be for burglars to pierce such a wall, even though they were equipped with the best of modern tools, and the same can be said of the flooring.

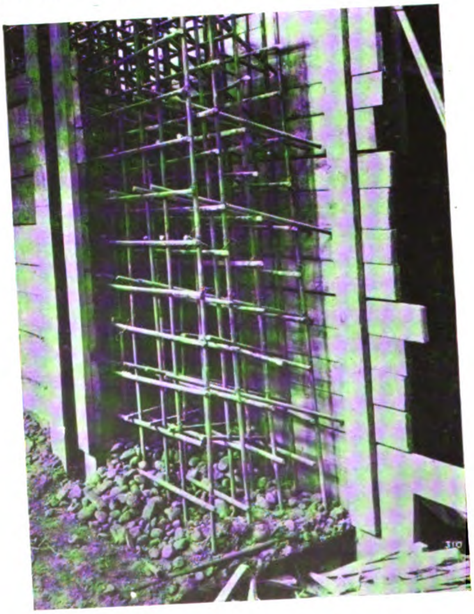


FIG. 16. MONT DE PIÉTÉ, MILAN.
Detail of Reinforced Concrete Walls to Vault in course of construction.

NEW USES FOR CONCRETE

AT HOME AND ABROAD.

Under this heading reliable information will be presented as to new uses to which concrete and reinforced concrete are put, with data as to experience obtained during the experimental stage of such new applications of these materials. The use of reinforced concrete as a substitute for timber in exposed positions is one of the questions of the moment. Railway sleepers, telegraph posts, fence posts, etc., of concrete are being tried. Similarly, efforts are at present being made to prove that reinforced concrete is an excellent substitute for brickwork, where structures of great height are required.—ED.

A REINFORCED CONCRETE GASHOLDER TANK.

A GASHOLDER tank of reinforced concrete, 84 ft. in diameter and 21 ft. 5 in. deep, was constructed about a year ago for the Key City Gas Company, of Dubuque. This tank, while not remarkable in point of size when compared with other examples of circular-tank construction in the same material, affords a good example of a carefully-planned method of work in erection, and the application of "indented" bars for all reinforcing.

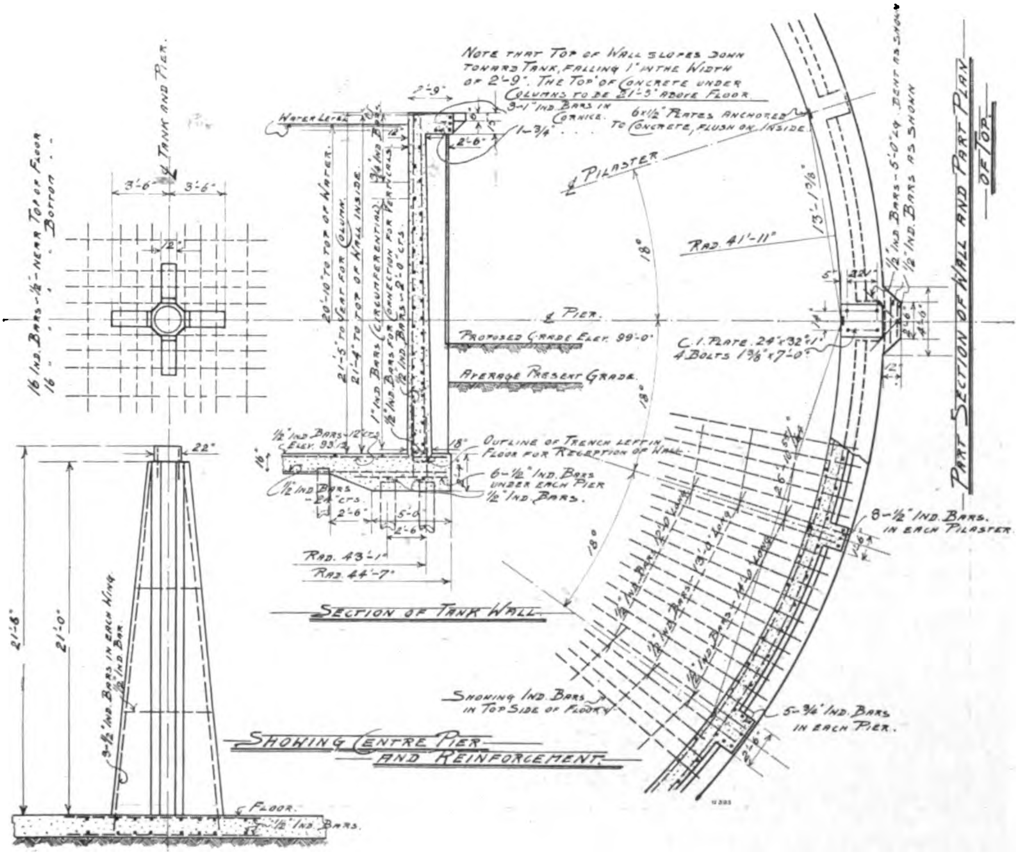

℄ Tank and Pier
3'-6"
3'-6"
12"
16 Ind. Bars-½"-near Top of Floor
16 " " " Bottom
22"
21'-8"
21'-0"
3-½" Ind. Bars in each Wing
½" Ind. Bar
Floor
½" Ind. Bars
Showing Centre Pier and Reinforcement
Note that Top of Wall slopes down toward Tank, falling 1" in the Width of 2'-9". The Top of Concrete under Columns to be 21'-5" above Floor
2'-9"
Water Level
3-1" Ind. Bars in Cornice
1-3/4"
2'-6"
12"
20'-10" to Top of Water
21'-5" to Seat for Column
21'-4" to Top of Wall Inside
1" Ind. Bars (Circumferential)
½" Ind. Bars for Connection for Verticals
½" Ind. Bars-2'-0" crs.
¾" Ind. Bars
½" Ind. Bars-12" crs.
Elev. 93'½
16"
½" Ind. Bars-24" crs.
2'-6"
5'-0"
2'-6"
18"
Outline of Trench left in Floor for Reception of Wall
6-½" Ind. Bars under each Pier
½" Ind. Bars.
Rad. 43'-1"
Rad. 44'-7"
Section of Tank Wall
6×½" Plates anchored to Concrete, flush on inside
℄ Pilaster
18°
18°
18°
13'-1⅜"
Rad. 41'-11"
℄ Pier.
Proposed Grade Elev. 99'-0"
Average Present Grade.
C. I. Plate 24"×32"×1"
4 Bolts 1⅜"×7'-0"
5"
22"
14"
2'-6"
4'-0"
12"
½" Ind. Bars-5'-0" lg. bent as shown
½" Ind. Bars as shown
Part Section of Wall and Part Plan of Top.
26'-10.5"
½" Ind. Bars 12'-0" long
½" Ind. Bars 13'-0" long
½" Ind. Bars 14'-0" long
8-½" Ind. Bars in each Pilaster
6"
Showing Ind. Bars in Top Side of Floor
5-¾" Ind. Bars in each Pier.
2'-6"

FIG. 1. PART PLAN AND SECTION OF REINFORCED CONCRETE GASHOLDER TANK.

The general construction of the tank is indicated by *Fig.* 1. The bottom is 5 ft. below the average grade of the site. The floor is normally 16 in. thick, and rests on piles spaced about 4 ft. 6 in. on centres; but under the wall it is 28 in. thick, and the pile spacing is reduced to 2 ft. 6 in. The floor rests directly on the piles (although a foundation of cinders and sand well mixed and tamped was put in between the pile-heads), and is reinforced only around the edges and under the centre pier. Below the floor are two reinforced concrete tunnels for the inlet and outlet pipes. The wall is 21 ft. high, 18 in. thick at the floor-line, and 12 in. thick under the cornice. The centre pier is made of reinforced concrete as indicated in *Figs.* 1 and 2. For the floor a 1–2·5–5 limestone concrete was used; the stone all passed a 2-in. ring, and had the dust removed. This mixture was also used for the cornice. The concrete for the walls was a 1–2–4 limestone mixture; the stone all passed a 1-in. ring, and had the dust removed. The size and location of the reinforcing bars are clearly indicated in *Fig.* 1. The reinforcement is all in "indented" bars. The circumferential bars were spliced by lapping. They were placed in lengths two bays long, the inside bars so as to lap alternately at the pilasters and the middle of the bays, and the outside bars so as to lap alternately at the piers and the middle of the bays.

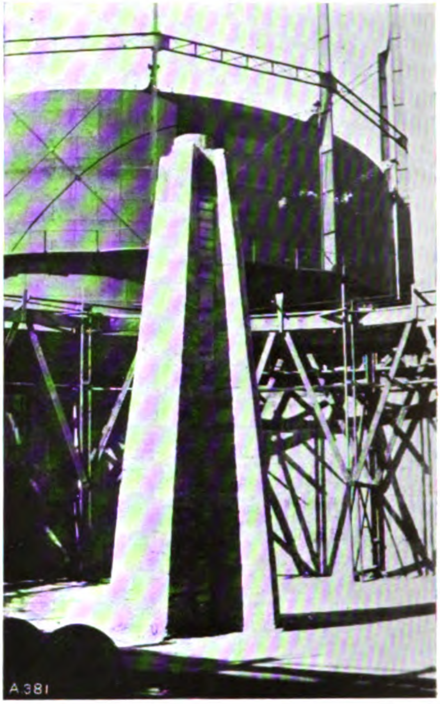


FIG. 2. PIER IN CENTRE OF TANK FOR HOLDER SUPPORT.

The general plan of construction was to put in the floor complete, leaving in it a groove or trench to take the bottom of the wall, moulding in the floor, also,

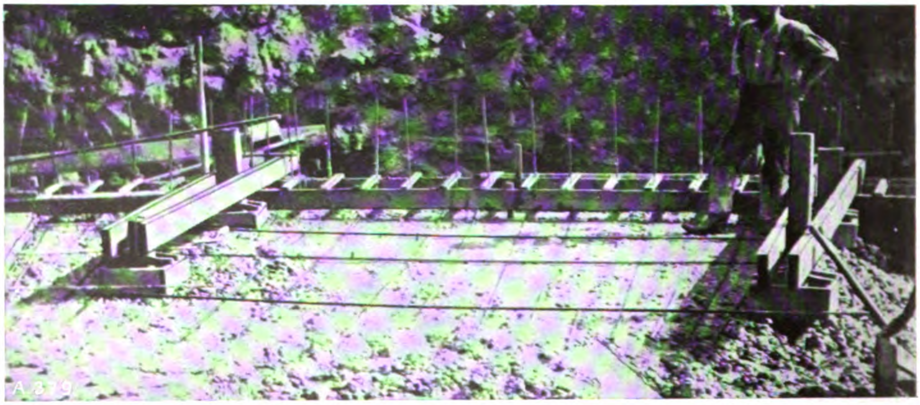


FIG. 3. FLOOR CONSTRUCTION: COMBING AND POSTS FOR SUPPORT OF FRAMES.
(Note boxes around posts. The boxes were taken away later, and the posts cut off, the space being filled with concrete.)

supports for the frames of the wall moulds, as the soft foundation material made it undesirable to rest the frames on the ground; and then to build the wall between forms which could be moved up as the work progressed, the complete circle of the tank being filled to the height of the form in one operation, thus making all joints in the work horizontal. The back-fill around the lower part of the wall was relied upon in the design as a support for the wall; and it was, therefore, carefully tamped in after the wall was completed.

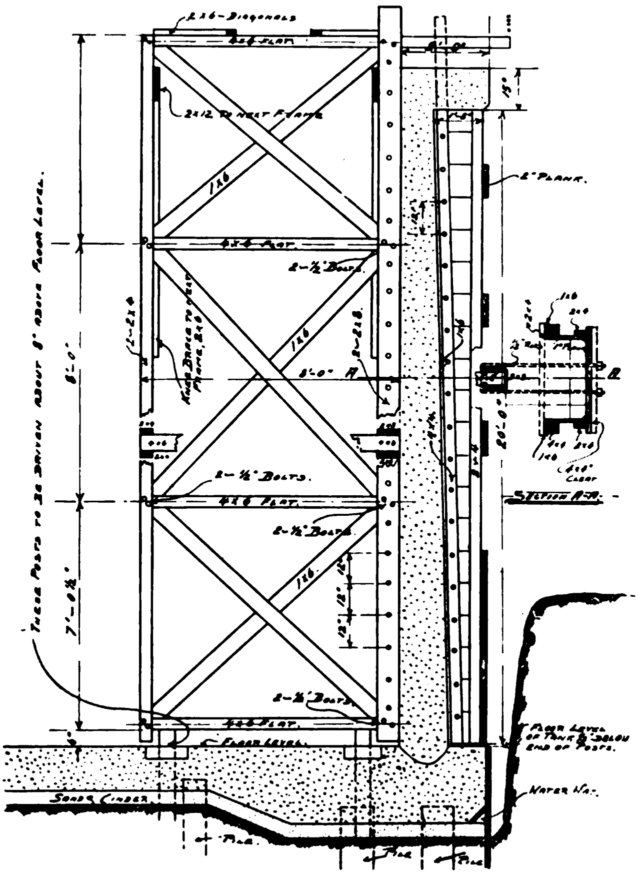


FIG. 4. DETAILS OF FRAME FOR INSIDE WALL FORMS.

Floor Construction.—The first work in constructing the floor was to drive the piles in the bottom of the excavation, and then to place the bed of sand and cinders. This being done, two circumferential rows of posts were driven round the outer edge of the foundation bed. The posts were located on the same radii as the wall buttresses. The upper portions of the posts were boxed round, so that, in placing the concrete for the floor, recesses would be left round the tops of the posts, which would enable them to be cut off below the floor level and covered by filling the recesses (*Fig.* 3). The purpose of these posts was primarily to carry the frame bents on which the inside wall forms were carried progressively upward. The lower half of each post was notched, so as to form a bond with the floor concrete, whereby the load of the mould frames would all be carried by the latter. Incidentally, the posts carried the forms for the circular grooves or trench in which the wall was seated.

To the tops of each pair of posts, radially to the tanks, were nailed two planks with ends projecting beyond the outer edge of the floor. To the projecting ends of these planks were fastened cleats extending downward, and on to these cleats were bent two lines of 1 in. by 6 in. boards, forming a circular bottomless trough round the tank space as the line of the wall. Small strips of board were then nailed across the top of the trough on equidistant radial lines, and from these were suspended two lines of vertical wall-bars. The trench forms being in place, concreting was begun.

The concrete was put in in sections, forms being provided for stopping off the day's work. These forms served the double purpose of making a mortise-and-tenon joint between each successive day's work, by setting the tops of the forms to an exact grade of templets between which the concrete could be floated level with straight edges. The object of the mortise-and-tenon joints was both to ensure water-tightness and to give a continuous beam action, the forms being so placed as to subdivide the floor into diamond-shaped panels. The concrete was handled from the mixer to the work in wheelbarrows. When placed, it was thoroughly tamped, roughly floated to the surface, and finally given a trowel finish.

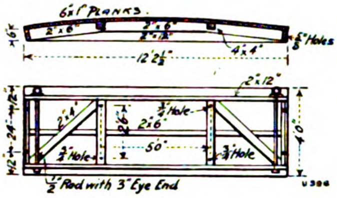


FIG. 5. SECTION OF FORMS FOR INNER FACE OF WALL.

Wall Construction.—As seen in *Fig.* 1, the wall is buttressed on the outside by alternate "pilasters" and "piers." The piers support the columns for the guide-frame, while the pilasters intermediate between the piers support the cornice, and break the outline of the tank, giving a more pleasing appearance.

The wall was constructed as follows: After the floor was completed, the posts driven into the bottom, as before noted, were cut off level 6 in. above the floor, and a bent for the wall form was erected on each radial pair. The construction of these bents is shown in *Fig.* 4. Each bent was raised by hand, and was carefully plumbed and centred; the proper angular distance between the bents was assured by setting each one on a line from the centre of the tank to a previously set point on the periphery of the floor. The bents were braced together round the tank as shown in *Fig.* 5. The pilaster and pier forms were next set in place directly in front of the bents, and braced in position. A pilaster form in position is shown in *Figs.* 4 and 6. These forms were boarded up completely on the two sides; but the rear face boards were placed only after concreting was begun and as the concrete was laid.

To mould the panels between the pilasters and piers and the corresponding spaces on the inside of the wall, curved sectional forms or shutters were inserted between, and fastened by the edges to the pilaster forms on the outside and to the bents on the inside. The outside shutters were exactly similar, except, of course, that they were concave instead of convex (*Fig.* 7). In operation, the shutters were first set up with their bottoms on the concrete floor. The edges of the inside shutter were bolted to the sides of the wall-posts of the bents; this left between the posts and the edges of the shutters triangular spaces which

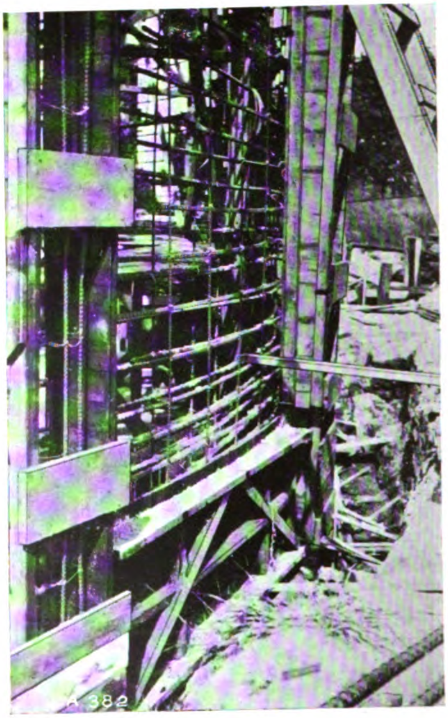


FIG. 6. PILASTER AND OUTER FORMS.

were closed off by vertical 2-in. strips of steel fastened to 1-in. square strips of wood. The edges of the outside shutters were lag-screwed to the 4-in. square posts of the pilaster forms. The face side of the shutters was oiled with crude oil when set, and again after the first shift; but it was not found necessary to oil the forms for every move. The forms were 4 ft. high, and were raised 3 ft., leaving one foot of the lower part lapping over the finished concrete. The forms were raised by means of blocks hung from a 6-in. by 4-in. timber placed across the top of the adjacent bents and pilaster forms. The forms were shifted the day after placing the concrete. At first it took almost a full day to get the forms for the full circle into their new position; but after two shifts this time was reduced to half a day. Much of the delay was caused by the ½-in. bolts tying the inner and outer moulds together at the intermediate verticles (see *Fig.* 5), which bolts became bent, and were very difficult to remove.

The 6-in. by ½-in. vertical steel strips moulded in the inside face of the wall at each pier and pilaster, shown in *Fig.* 1, were used in connection with the mould frames as follows: The plates were bolted to the outside face of the frames, covering the 6-in. space between the two uprights of each frame, being bolted in such position as to bring their inner face flush with the outside of the frame (or the inside of the wall). Anchors fitted to these plates at intervals of 3 ft. served to hold them firmly to the wall. During construction this rigid connection between frame, plate, and wall acted to hold the frame firmly in place, so that the diagonal bracing of each bent could be removed to make room for wheelbarrow runways. The runway on the inside rested first on the second horizontal of the frame, and the concrete was dumped from a platform outside through the bars upon a platform on the runway; thence it was taken by wheelbarrow and dumped into place. The runway was raised to successive horizontals as the work progressed.

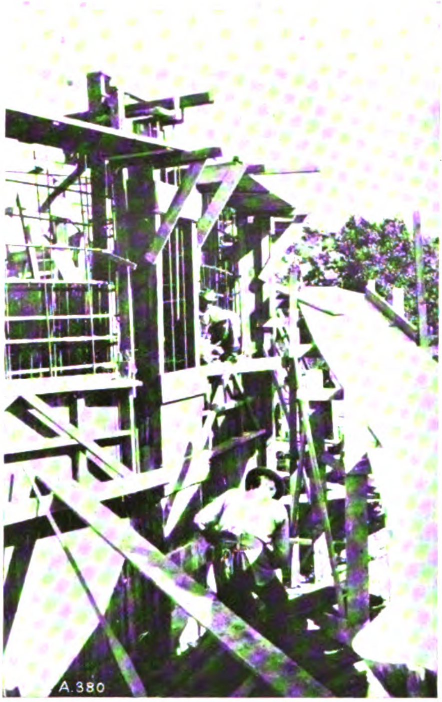
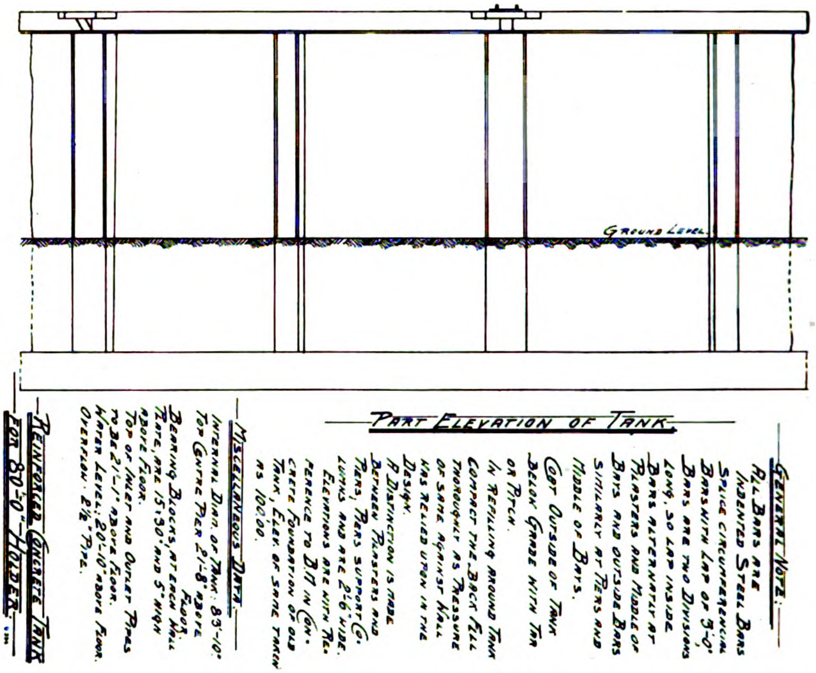


FIG. 7. OUTSIDE FORMS IN PLACE AND RUNWAY.

Reinforcement.—The sizes and distribution of the reinforcing steel are given in *Fig.* 1. The placing of the floor reinforcement has already been referred to. The wall reinforcement was all placed and wired up before the wall concreting was begun. This work was relatively simple. The bars came in lengths of about 30 ft., and this gave a lap of about 3 ft. on the circumferential bars, the laps being located at every second division, as already shown. The lapping ends of the circumferential bars were first loosely hooped with two ties of No. 10 wire; then the verticals were placed, and the circumferential bars were pulled up to their proper levels and wired


Ground Level
Part Elevation of Tank.
General Note:—
All Bars are Indented Steel Bars
Splice circumferencial Bars with Lap of 3'-0".
Bars are two Divisions long, so lap inside.
Bars alternately at Pilasters and Middle of Bays and outside Bars similarly at Piers and Middle of Bays.
Coat Outside of Tank below Grade with Tar or Pitch.
In Refilling around Tank compact the Back Fill thoroughly as Pressure of same against Wall has relied upon in the Design.
A Distinction is made between Pilasters and Piers, Piers support Columns and are 2'-6" wide.
Elevations are with Reference to B.M. in Concrete Foundation of old Tank, Elev. of same taken as 100.00.
Miscellaneous Data.
Internal Diam. of Tank: 83'-10".
Top Centre Pier 21'-8" above Floor.
Bearing Blocks, at each Wall Plate, are 15×30" and 5" high above Floor.
Top of Inlet and Outlet Pipes to be 21'-1" above Floor.
Water Level: 20'-10" above Floor.
Overflow · 2½" Pipe.
Reinforced Concrete Tank for 80'-0" Holder.

to the verticals. The lapping was done in such a way as to allow the concrete to surround each bar, as reliance for splicing was placed wholly on the concrete.

Some Cost Items.—The cost of unloading the reinforcing steel from the cars and placing it in the structure was $7 (29s. 2d.) per ton. The labour of mixing and placing the concrete amounted to 3.4 hours per cubic yard for the floor, 5.2 hours per cubic yard for the wall (including pilasters and piers), and 5.4 hours per cubic yard for the cornice. The cost of the forms cannot be expressed so satisfactorily. Generally speaking, and making no allowance for the value of lumber after use, 9 c. per square foot of wall would cover the cost of materials, fabrication, and taking down and putting up the forms.

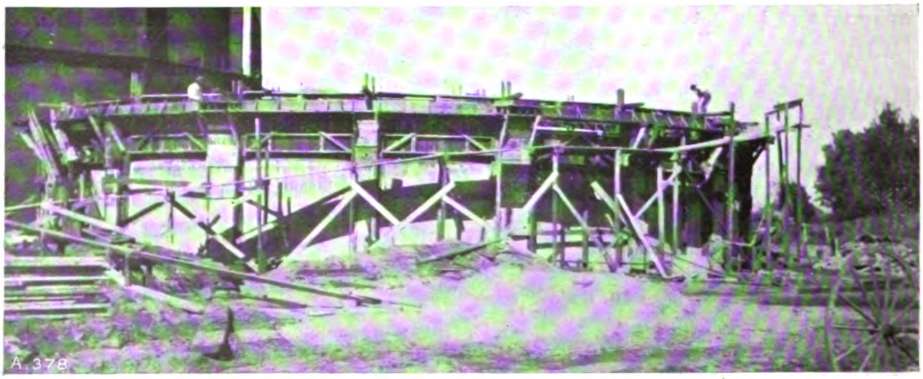


FIG. 9. REINFORCED CONCRETE TANK ALMOST COMPLETED.
Showing forms of cornice construction, and runway.

INDUSTRIAL NOTES.

These pages have been reserved for the presentation of articles and notes on proprietary materials or systems of construction put forward by firms interested in their application. With the advent of methods of construction requiring considerable skill in design and supervision, many firms nowadays command the services of specialists whose views merit most careful attention. In these columns such views will often be presented in favour of different specialities. They must be read as ex parte statements—with which this journal is in no way associated, either for or against—but we would commend them to our readers as arguments by parties who are as a rule thoroughly conversant with the particular industry with which they are associated.—ED.

TESTS ON A "KLEINE" PATENT FIRE-RESISTING FLOOR.

SOME interesting load and impact tests were carried out at Irongate Wharf, Paddington, on October 31st, 1906, on two "Kleine" patent fire-resisting floors under the direction of Mr. A. T. Walmisley, in the presence of several gentlemen in the architectural and engineering professions.

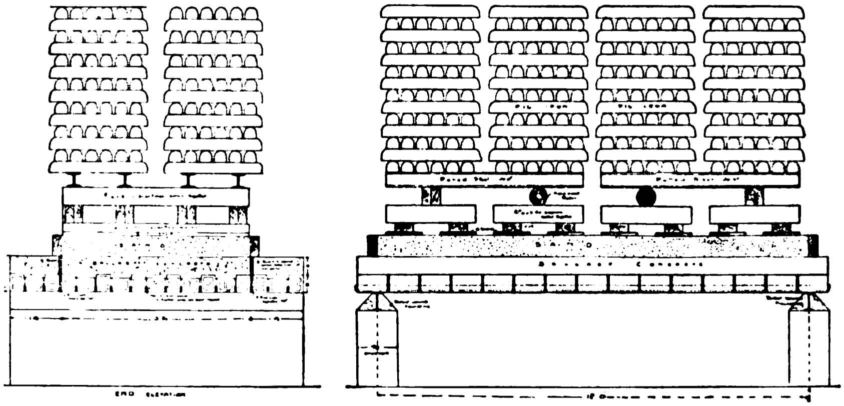
The First Test.

The larger of the floors tested had a clear span of 12 ft., and the loaded width was 5 ft. 3½ in. It was supported at the ends upon rolled metal joists 6 in. by 3 in. in section, held in position by ballast concrete flanching on the top of dwarf walls 13½ in. in width, so that the underside of the slab was 2 ft. 7½ in. from the ground. The floor was constructed with hollow bricks measuring 6 in. by 4 in. by 10 in., placed alternately flat and on edge, with a flat iron bar embedded vertically in the centre of each longitudinal joint between the bricks. This bar, which was 1¾ in. by ⅛ in. thick, ran from end to end of the floor, and was held in position along the joint by ordinary cement mortar, and bent over at the ends. An additional width of 1 ft. 5½ in. was built on to each side in a similar fashion, but this portion was separated from the central part by ½-in. boarding placed longitudinally, so that only the width of 5 ft. 3½ in. was subject to deflection. Concrete was laid over the area under test, bringing the total thickness of the slab up to 12 in., and was composed of 1 part Portland cement to 6 parts Thames ballast. This concrete is used to take up the compressional strain, the metal bars absorbing the tensional strain.

Sand to the depth of 6 in. was spread over the floor, being kept in place by planks set on edge. Over this metal joists, supported by timber bearers crossing

KLEINE PATENT FIRE-RESISTING FLOOR

GENERAL ARRANGEMENT OF TEST



one another, formed a grid platform upon which the load was placed. The material used for the loading was pig-iron, batches of which were very carefully weighed and then placed upon the floor, piled in regular layers with intervening spaces at intervals, and was put in position from a platform which had been erected round the floor.

At 12 o'clock (noon) on the day before the test the loading was commenced, and kept up through the afternoon until a load of 5 cwt. per sq. ft. had been applied. At 2.27 p.m. on the following day the deflection was measured, and found to be nil. Increase in the loading was then resumed, and sixteen minutes later, when the load was 5.96 cwt. per sq. ft., there was no change in the deflection. Loading was continued, and at 3.5 p.m. the deflection was found to be $\frac{1}{20}$ in., while after another 20 minutes the deflection had increased to $\frac{1}{10}$ in. The loading was still proceeded with, and the deflection was again measured at 3.35 p.m. and found to be $\frac{3}{20}$ in., when the load was 7.4 cwt. per sq. ft. The deflection was measured once more at 3.45 p.m., when it was $\frac{1}{5}$ in., the load distributed over the area of 63½ sq. ft. being then 25 tons 1 cwt. 1 qr. 14 lbs. Then, at 3.50 p.m. the floor collapsed, when there was a load of 7.9 cwt. per sq. ft.

When the floor was examined after its fall, it was discovered that the tension bands had been pulled through from one end, and slightly deflected, but they were unbroken. It was found, however, that the concrete had not been well mixed, that the ballast used was not of good quality, and that the cement had not properly set, all of which facts combined to throw an additional stress upon the brick floor.

The Second Test.

The second and smaller floor, upon which the fall tests were made, was built in a similar manner to the other, with these two exceptions:—(1) That all the bricks were placed on edge, and (2) that no concrete was employed, as the makers only use that material for spans of over 9 or 11 ft. The floor had a span of 8 ft. 6 in., being covered with sand, and it had a further load of 4 cwt. per sq. ft. This load was taken away before the fall tests were made, though the sand remained in place.

A stone, 12 in. deep, and weighing ¾ cwt., was then allowed to drop upon the sand-covered floor from a height of 8 ft. Upon examination the sand was found to have been compressed at the point of impact, the indenture in the centre being about 2 in. The floor itself was unhurt. The sand was next cleared away, and the weight was dropped on to the middle of the floor, directly over a joint, but this time the height was increased to 9 ft. The surface of the floor on the upper side was then seen to have been chipped a little, while a slight transverse crack appeared along one of the joints. The weight was then dropped a third time from the height of 9 ft. on to the same spot, with the result that the lower half of a couple of the bricks fell out, the breach on the under side of the floor being about 18 in. in length. Once again the stone was allowed to fall upon the same point of impact, and a hole was made right through the bricks, measuring about 8 in. square on the upper side.

The stone was dropped for a fifth time on to a different place, immediately over a brick. A hole was made in the brick, and a small crack appeared, but otherwise there was no visible damage.

The results of these tests should be considered satisfactory. As has been observed, the large floor was only constructed to bear a safe load of 2 cwt. per sq. ft., yet, when the fabric finally gave way, a load of 7.9 cwt. per sq. ft., nearly four times that specified, was distributed over the floor. In the ordinary form of building construction, too, the slab would have been supported at the sides by steel joists. Also, as we have said, the concrete had been badly mixed, and had not properly set. Considering all these facts, it is only reasonable to assume that had the conditions been more favourable the floor would have sustained a considerably greater load.

The flooring is making rapid headway in London, and may be seen in construction on application to the Company at 9, St. Helen's Place, E.C.

OCT 30 1917

ARTICLES AND PAPERS

AT HOME AND ABROAD.

The following articles and papers are among the most important published at home and abroad during October and November of 1906:—

I.—CONCRETE CONSTRUCTION.

Articles.

Double-Track and Four-Track Concrete Bridge on the Philadelphia and Reading Railroad Lines: an *ill.* article describing (1) a double-track concrete bridge at Pennypack Creek, 348 ft. long over all, about 80 ft. at extreme height above river bed, and nearly 33 ft. wide over all. The pier shafts are 8 ft. wide by 34 ft. long. Two channel piers have pointed cut-waters at both ends, carried above high water. (2) A four-track across Neshaminy Creek, comprising two abutments with wing walls and five intermediate piers supporting five 65 ft. and one 52 ft. full-centre arch span.—*Eng. Rec.*, 13.10.06.

Concrete Viaducts on the Key West Extension of the Florida East Coast Railway. By George P. Carver: there are some 500 reinforced concrete segmental and semicircular arches of from 45 ft. to 60 ft. span, and the entire length is about 6 miles. Approximately, the following materials will be required:—300,000 barrels of cement, 225,000 cu. yds. of sand, 200,000 cu. yds. of crushed stone and gravel, and 5,000 tons of steel reinforcing bars. The piers for the viaducts are erected in from 6 ft. to 30 ft. of water on very hard but porous lime rock and coral, which is overlaid with sand. The method of construction is described, and the article is *ill.* by photographs and diagrams.—*Eng. Rec.*, 20.10.06.

Remarkable Settlement of Concrete Buildings in Tunis. By P. Fountain: the Société des Minoteries Tunisiennes have had under construction for some time three large buildings for the storage of wheat and flour. The centre one of these buildings was observed to be gradually deviating from the perpendicular, the movement continuing for several hours until an angle of 25 deg. was reached. The fall of the structure was considered imminent, but the engineer and contractor thought that it might be righted, and accordingly set about restoring it into position. The floors on the elevated side were weighted with 2,000 tons of sand, and the same quantity of flour, while excavations were made alongside the foundations on the higher part, and in a few days the edifice once more stood upright. Soon after, however, one of the outer buildings was seen to be subsiding, but similar means were taken to place it once more in position. As a result the edifices are some 15 or 18 ft. below the intended level, but they remain whole and their parts undisturbed, a splendid testimony to the cohesion and tenacity of concrete structures. There are some interesting photographs reproduced.—*Eng. Rec.*, 3.11.06.

II.—REINFORCED CONCRETE CONSTRUCTION.

Articles.

Reinforced Concrete Works at Rotterdam.—*Zement u. Beton.*, 15.10.06.

Reinforced Concrete and Earthquakes: *ill.* of a remarkable subsidence in Tunis, where a reinforced concrete mill building has fallen over to a large angle from the vertical, without cracks or other injury to the structure.—*Le Ciment*, Oct., 1906.

The Undosa Bathing Establishment at Stamberg. By G. Schellenberger: a description, with detail drawings, of a difficult work in reinforced concrete at a lake-bathing establishment.—*Beton u. Eisen*, Oct. and Nov., 1906.

Sea-Dykes in Reinforced Concrete. By R. R. L. de Muralt, Zeirikzee.—*Beton u. Eisen*, Nov., 1906.

Details of the Catskill Aqueduct, New York: plans and specification for a portion of this 82-mile aqueduct have been published, and are reproduced. The first contract comprises 41,880 ft. of trench and embankment conduit, three tunnels 2,350, 11,430, and 900 ft. in length respectively, and 210 ft. of experimental reinforced concrete pipe at an inverted syphon across a brook. In open trench and an embankment the aqueduct will be constructed of Portland cement concrete, 17 ft. high by 17½ ft. wide inside. Lining of tunnels of same material, 17 ft. high by 13 ft. 4 in. wide at the clear. The reinforced concrete pipe will be 11 ft. in diameter inside, and 8 in. thick. The general construction of the cut-and-over portion to be followed is that the invert of the section will be laid in one operation, and the side walls and arch in another. Special conditions have to be observed by the contractors as to building methods, etc.—*Eng. Rec.*, 10.11.06.

III.—STEEL CONSTRUCTION.

Articles.

Cantilever Bridge over the Seine at Passy. By R. Bonnin: article describing the construction of this bridge, which is a double-deck structure, having a wide main deck for vehicles and pedestrians, and a two-track upper deck for the Metropolitan Railway. Crossing two arms of the Seine, there are virtually two bridges. The one over the main channel has three spans, the middle one 177 ft. between centres of piers. The bridge across the secondary channel has a middle span of 138 ft. Both crossings of pure cantilever type, side openings being the anchor arms, and the middle opening containing a suspended span. The upper deck is supported by columns standing on interior trusses of lower viaduct. Details of sub-structure, superstructure and elevated viaduct are given, and methods of erection are described. The *ills.* are very interesting.—*Eng. News.*, 15.11.06.

EDITORIAL MEMOS.

CONTRIBUTIONS.—Original contributions and illustrations are specially invited from engineers, architects, surveyors, chemists, and others engaged in practical or research work. MSS. should be written on one side of the paper only, giving full name and address of the author, accompanied by a stamped addressed envelope for reply. Plans and Sections should be in black line on white ground.

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